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Putting waste to work

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Centre for Integrated Biowaste Research

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UPDATE FROM THE PROGRAMME MANAGER

Vermicomposting in the sunny Kapiti Coast.

The CIBR team have been busy in the run up to the end of the 2015-2016 financial year. As usual, the CIBR Annual Report is a testament to the achievements of the entire team over the past 12 months. The report highlights include; 18 peer reviewed journal publications, 6 completed research postgraduate projects, 23 conference presentations, 7 commissioned reports and 10 awards for science achievement. CIBR is also growing its network by establishing new formal collaborations with the University of Auckland, the Chinese Academy of Agricultural Science and Shanghai University. These valued partnerships will promote the development of our capability and help foster new talent in the biowaste research space. Overall, a very successful year with some great science outputs.

This newsletter details some of the great work we've been doing this year, including an update from our long term trial at Rabbit Island, where our 2015 data now means we have 24 years of information about land application of biosolids to forestry. We also have an update from a new research project that looks at vermicomposting biosolids with plasterboard to remove these products from landfill and create a beneficial end product.

The CIBR team are actively supporting students who are studying in this area and this issue of the newsletter includes articles on two current PhD projects. Olivier Laroche (Cawthron Institute/University of Auckland) is looking at developing innovative monitoring methodology, while Nadir Saleeb (Lincoln University) is studying the environmental impacts of silver nanoparticles. See their articles for more details on these fantastic projects. On the subject of students, Morkel Zaayman has just been awarded two travel scholarships to present his PhD findings at the International Water Association 2016 conference in Gdansk, Poland. The scholarships are from the University of Canterbury and the Claude McCarthy fellowship – well done Morkel.

Finally, this has been a really busy time for promoting science in schools. We have rolled out the "Up the Pipe" program to several different groups in the past few months – see Sarah Quaife's article on page 8 for more details of this rewarding work.

I hope you enjoy this issue of the newsletter – as always if you would like to contribute to our next issue please contact our newsletter editor sarah.quaife@esr.cri.nz.

Jacqui Horswell

VERMICOMPOSTING OF BIOSOLIDS AND PLASTERBOARD IN THE KAPITI COAST

Sarah Quaife and Staci Boyte

CIBR has joined forces with Laybys NZ and the Kapiti Coast District Council to investigate the viability of vermicomposting biosolids with plasterboard (also known as GIB board or drywall) with the intent to divert these waste products from landfill and instead create a beneficial usable product.

Many New Zealand wastewater treatment plants, including the Paraparaumu Wastewater Treatment Plant, dispose of their settled, thermal dried, biosolids in landfills. Other waste to landfill includes plasterboard, as part of construction and demolition waste from building sites (estimated range 2.4-3.6% landfill waste is plasterboard).

Both of these wastes in landfill take up space. Under the anaerobic conditions that often exist in landfills, hydrogen sulfide can be produced by plasterboard while biosolids added to landfill can contaminate soil or water and, produce methane gas.

Vermicomposting is the process of non-thermophilic biodegradation and stabilization of organic materials by interactions between earthworms (*Eisenia fetida* or "Tiger worms") and microorganisms. 'Vermicompost' originated from the latin words *vermes* meaning "worms" and *composite/compositum* meaning "something put together". Vermicomposting was chosen for this study in preference to traditional composting because it is reported to be faster and requires less manual work. It also recycles nutrients more efficiently, creates a more homogenous and aesthetically pleasing product and, has a greater acceptability within the wider community.

Vermicomposting with biosolids has not previously been trialled in New Zealand with plasterboard as the bulking agent or feedstock. Therefore, in order to assess the parameters for composting of this kind, duplicate custom vermicomposting units were set up with differing ratios of biosolids to bulking material to assess the best mixture for expediency and also premium product output.

Greenwaste was also added to each treatment in order to boost the carbon to nitrogen (C:N) ratio, which is required for composting worms to survive. The mixtures of biosolids, plasterboard and greenwaste are compared with a biosolids and green waste mixture only, serving as the control. We know from previous research and industry practices that biosolids combined with greenwaste/wood pulp can be an effective composting mixture and the aim here is to see that the addition of plasterboard doesn't significantly slow down the process or create a low-premium product. Plasterboard is composed of gypsum with a paper lining and has the potential to help balance the C:N ratio, absorb excess water, aerate the compost and reduce the ammonia smell from biosolids. In addition, as a final product, gypsum can be used as a soil amendment in agriculture to improve permeability in clay soils and provide calcium and sulphur for plant growth.

Field technician checking on the vermicomposting process.

Tiger worms (Eisenia fetita) in control mixture.

Each month samples will be analysed to monitor the vermicomposting process and determine its completion. We aim to determine how effective a) the vermicomposting process is with plasterboard as the bulking material; b) the system is in reducing metal concentrations and pathogens to grade a standards and; c) the compost is at enhancing plant growth. We will report our findings in further issues of the newsletter.

SILVER NANOPARTICLES, AN EMERGING ISSUE IN BIOSOLIDS?

Nadir Saleeb[1], Ravi Gooneratne[1], Jo Cavanagh[2], Brett Robinson[1]

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Silver (Ag) is a chemical element that is non-essential for life and has a relatively low background concentration in Earth's crust (0.07 mg/kg). Increasingly, Ag is being incorporated into household products such as washing powders and personal-care products including shower gels and deodorants. Silver effectively removes foot odour and is incorporated into socks. The beneficial effects of Ag in these roles relates to its powerful antimicrobial properties. These products use Ag nanoparticles, rather than ionic Ag, because the former is less toxic to humans. In all the aforementioned cases, the Ag ends up in the sewer. Therefore, we might expect that biosolids would contain elevated concentrations of Ag. The beneficial reuse of these biosolids could result in the silver entering soil where it may interact with soil organisms and plants. As a contaminant, Ag has been poorly studied. Nadir Saleeb, a PhD student at Lincoln University, is seeking to understand the behaviour of Ag in the environment and in particular, elucidate any differences between Ag nanoparticles and ionic Ag.

A survey of biosolids from around New Zealand revealed Ag concentrations of 6 – 18 mg/kg Ag (Fig. 1), far in excess of Earth's crustal average, with two outlying samples from one small treatment plant containing 90 mg/kg Ag. Therefore, we would expect biosolids application to land to increase soil Ag concentrations. Silver concentrations in biosolids are likely to increase with the growing number of Ag-containing household products.

Batch sorption experiments tested the retention of Ag by soil. Both the Templeton Silt Loam and a Pukekohe granular soil strongly retained Ag with Kd values (sorbed / solution concentration quotients) similar to that of other trace element cations. This indicates that Ag will accumulate in soil. Interestingly, the Ag nanoparticles were more strongly retained by the soil compared to Ag cations (Fig. 2). This would indicate that Ag nanoparticles are less likely to interact with plants and soil organisms.

The toxicity of Ag in soil was tested using earthworms (*Aporrectodea caliginosa*). The results showed concentrations of 390 mg/kg Ag nanoparticles and just 11 mg/kg Ag ions killed 50% of the earthworms. Similar experiments using plants showed that biomass was negatively affected above 75 mg/kg for both Ag ions and Ag nanoparticles (Fig. 3).

Other studies have shown that Ag nanoparticles slowly convert to ionic Ag, with the timeframe dependent on several environmental factors. This indicates that Ag nanoparticles applied to soil via biosolids will convert to Ag ions and become more toxic. Our preliminary studies indicate that Ag in biosolids is unlikely to reduce plant growth or result in unacceptably high Ag concentrations in plant tissues, where it may affect ecosystems or human health. Nevertheless, Ag in biosolids is likely to affect soil organisms, such as earthworms, which may subsequently affect soil fertility. An investigation into the effects of Ag on soil microbes is warranted. Given the increasing use of Ag in personal products, we would expect Ag concentrations in biosolids to increase, making Ag an emerging environmental contaminant of concern.

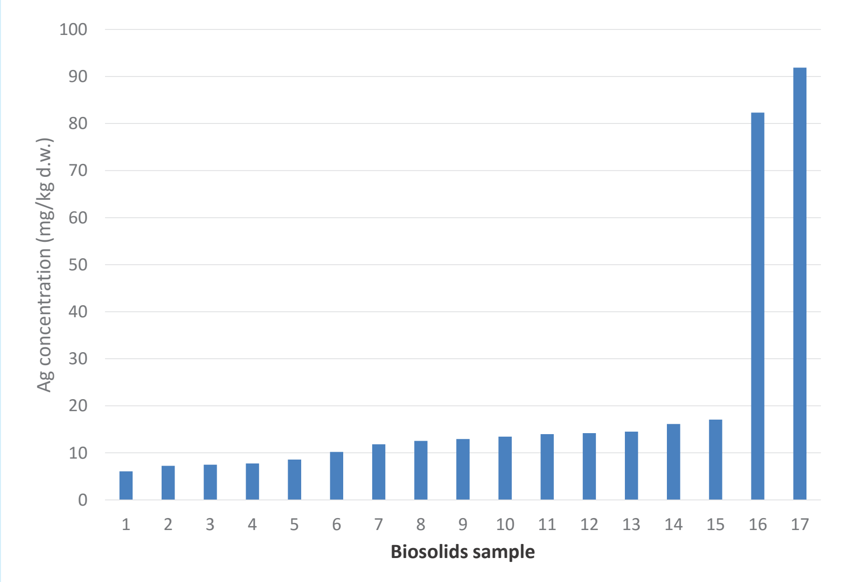

Fig. 1. Silver concentration (mg/kg dry weight) in 17 biosolids samples from around New Zealand. Note that the Templeton Silt Loam, analysed as a control, contained <5 mg/kg Ag.

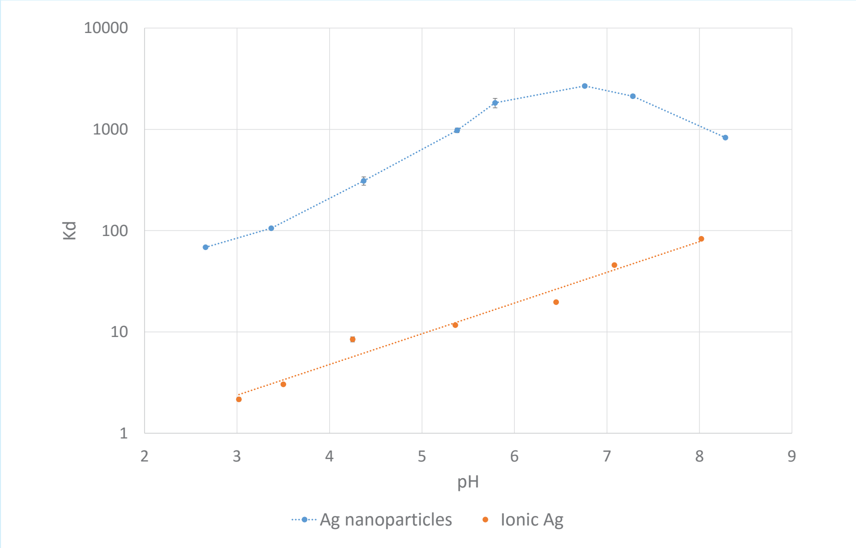

Fig. 2. The relative sorption (as indicated by Kd, the sorbed/solution concentration quotient) of Ionic Ag and Ag nanoparticles at 300 mg/L in ambient solution.

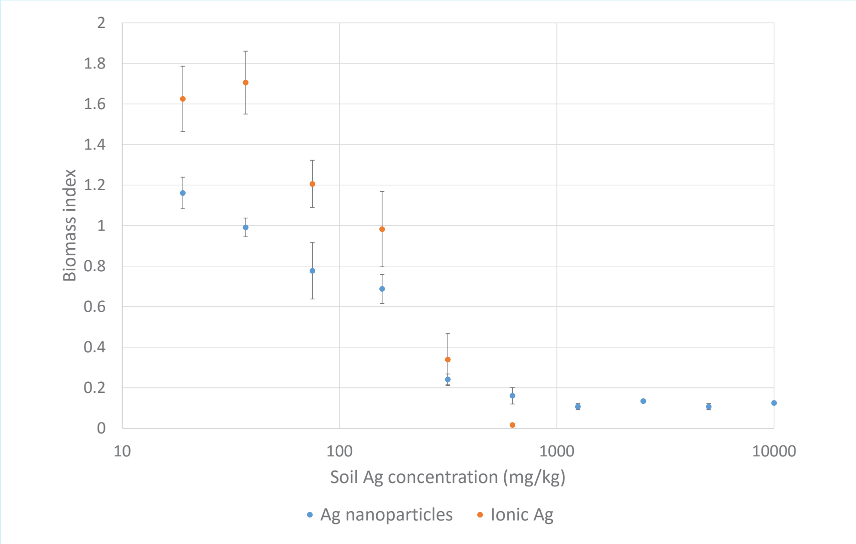

Fig. 3. The biomass index (treatment / control biomass quotient) of Lolium perenne (perennial ryegrass) in soil spiked with either Ag nanoparticles, or ionic Ag. Note that the ionic Ag was applied in the form of nitrate which likely resulted in the biomass index>1 at the low ionic-Ag treatments.

UPDATE FROM THE SOIL SCIENCE TEAM – IMPROVING TREE NUTRITION AND GROWTH OF RADIATA PINE FORESTS THROUGH SUSTAINABLE LAND APPLICATION OF BIOSOLIDS AT RABBIT ISLAND

By Jianming Xue

The CIBR soil science team has been conducting research on the environmental, ecological and economic impacts of repeated applications of biosolids to a radiata pine plantation at Rabbit Island. The research aims to develop sustainable land application of biosolids for the Nelson community, and provides indicative research findings for land application of biosolids throughout New Zealand. This newsletter provides updated information about beneficial effects of repeated biosolids application on improving foliar nutrition and tree growth of radiata pine plantation at Rabbit Island.

Beneficial use of biosolids as a supplemental fertiliser and soil amendment is one of the most common options for biosolids management. In New Zealand, application of biosoilds on forest land is preferred because it can reduce the risk of contaminants entering the human food chain and it can also increase tree growth and subsequent economic returns. Treated biosolids from the Nelson Regional Sewage Treatment Plant have been applied to a 1000-ha radiata pine forest plantation at Rabbit Island, near Nelson City, since 1996. A research trial was established on the site in 1997 to investigate the long-term effects of biosolids application on soil, groundwater quality, tree nutrition and growth. Biosolids have been applied to the trial site every three years (1997, 2000, 2003, 2006, 2009 and 2012) at three application rates: 0 (Control), 300 (Standard) and 600 kg N/ha (High). Tree nutrition status and growth are monitored annually, groundwater quality quarterly and soil properties every three years to determine both the risks and benefits and sustainable application rates as well. The latest foliage sampling and growth measurement of radiata pine at the Rabbit Island biosolids research trial were completed in March 2015 and July 2015, respectively (Fig. 1). Here we update our recent findings on the impact of repeated biosolids application on tree nutrition and stem volume growth, focusing on data collected in 2015.

Fig.1 Effect of long-term biosolids application on needle (left) and tree (right) growth of radiata pine at Rabbit Island in Nelson.

Treatment means of foliar nutrient and heavy metal concentrations in 2015 are shown in Tables 1 and 2. Biosolids application significantly increased foliar N, Mg, B, Cd and Ni concentrations, but reduced foliar Ca, Mn and Al concentrations.

Table 1: Effect of biosolids application on foliar nutrient concentrations in March 2015.*

Treatment	N	P	K	Ca	Mg	Zn	Cu	B	Fe	Mn
	%					mg kg $^{-1}$				
Control	1.40 a	0.14 a	0.60 a	0.20 a	0.14 a	20 a	2.6 a	14 a	35 a	251 a
Standard	1.43 a	0.14 a	0.58 a	0.18 a	0.17 b	19 a	2.5 a	17 b	36 a	147 b
High	1.58 b	0.14 a	0.59 a	0.16 b	0.18 b	22 a	2.6 a	17 b	40 a	165 b

**Values within a column followed by the same letter do not differ significantly (p= 0.05).*

Table 2: Effect of biosolids application on foliar heavy metal concentrations in March 2015.*

Treatment	Al	Pb	As	Cd	Cr	Ni
			mg kg $^{-1}$			
Control	56 a	1.68 a	0.39 a	0.80 a	0.078 a	7 a
Standard	45 b	1.54 a	0.42 a	0.80 a	0.073 a	14 b
High	46 b	0.97 a	0.35 a	0.88 b	0.078 a	18 b

**Values within a column followed by the same letter do not differ significantly (p = 0.05).*

Foliar analysis has consistently shown that natural soil N supply in the Rabbit Island radiata pine forest is not satisfactory, with foliar N concentration of the Control treatment remaining consistently well below 1.5% N (Fig. 2, left), a threshold value below which radiata pine may benefit from N fertiliser (Will 1985).

Successive applications of biosolids have produced a consistently positive response in foliar N concentration in the subsequent assessment when compared with Control trees (Fig. 2, left). The boost in foliar N generally declined over a period of several years following an application. However, this pattern was not so obvious during the period of last two applications. This could imply that the biosolids-derived residual N in the soil might become more influential than the freshly applied biosolids N on foliar N concentration. Following the 2012 application, foliar N concentrations in the Standard and High treatments were 0.03 and 0.18 percentage points respectively greater than the Control in 2015 (age 24).

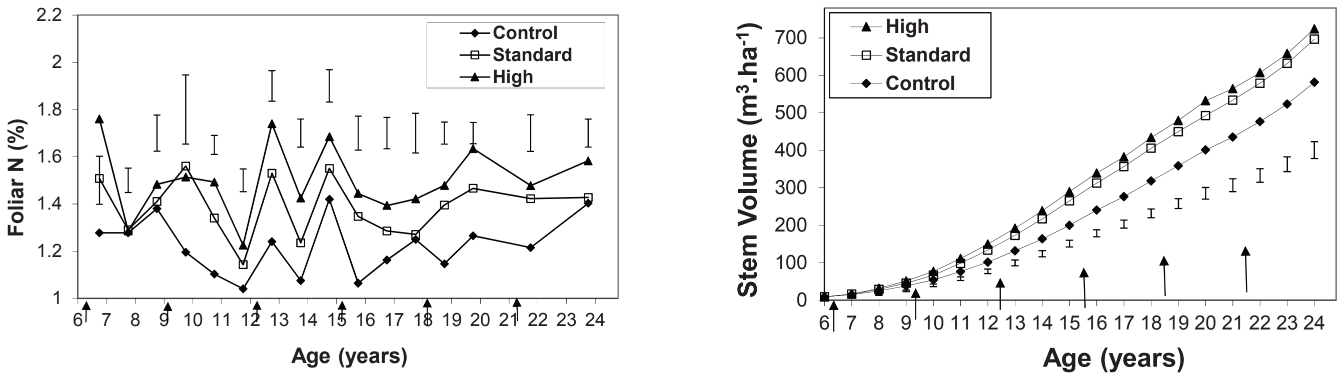

Fig. 2. Cumulative effect of five biosolids applications on foliar N concentration (left) and tree stem volume (right) in 2015. Arrows indicate time of biosolids application. Error bars show least significant differences (P < 0.05) for comparisons among the treatments.

As a result of improved N nutrition, application of biosolids significantly increased tree height and diameters (data not shown) and consequently tree stem volume since the first biosolids application in 1997 (Fig. 2, right) of radiata pine. Stem volume remained significantly greater in plots with biosolids applied than those with no biosolids application. In 2015, at tree age 24 years, stem volume of the High treatment (725 m3 ha-1) was 25% greater than the Control (582 m3 ha-1), and stem volume of the Standard treatment (697 m3 ha-1) was 20% greater than the Control, indicating a substantial gain in productivity. The maximum growth differential between treated and untreated trees occurred between ages 10-14 years (Fig. 2, right). Importantly, the increased stem volume achieved over these years appears to be firmly locked in. Although the difference in growth rate is now narrowing, there is no sign that the difference in total volume is closing.

In conclusion, repeated applications of biosolids have proved to be very beneficial to trees growing on this site. Effectively they have transformed the forest site from one of relative low productivity to moderately high productivity without causing significant adverse environmental and ecological impacts. Further monitoring is warranted to assess the long-term fate of biosolids-derived N, P and heavy metals in the receiving environment.

ENHANCING BIOMONITORING THROUGH ENVIRONMENTAL DNA ANALYSIS

Olivier Laroche, PhD Candidate at the UoA / Cawthron Institute

The impacts of micro-contaminants entering the environment through human activities and waste can be subtle. Taking advantage of the latest development in molecular techniques, my research project aims to develop an innovative monitoring methodology that relies on a weight of evidence approach to assess anthropogenic impacts. More specifically, it proposes to 1) apply DNA metabarcoding to develop a multi-taxa molecular monitoring tool for assessing offshore mining activities; 2) link expression of key stress and functional genes to specific environmental disruption using RT-qPCR; 3) study the differential environmental effects of oil and gas drilling and production activities by analysing and correlating the expression of biomarkers with population level effects; and 4) discuss ways of improving environmental management of offshore mining activities by reviewing major environmental policies, legislations and monitoring programs applied abroad. Although my research focuses especially on seaward mining activities, application of metabarcoding and RT-qPCR hold great promises for cheaply and quickly providing a greater understanding of ecological impacts from all sorts of stressors (micro-pollutants, pesticides, pharmaceutical products, etc.) and in all sorts of mediums (e.g. water, sediment, feces, biosolids, etc.).

In the first part of our study, we evaluated the applicability of foraminiferal-specific metabarcoding to monitor offshore drilling activities, and compared the response of foraminiferal environmental DNA/RNA and morphologically identified macroinfaunal communities to shifts in environmental conditions.

Our results demonstrated that macroinfaunal and foraminiferal assemblages expressed similar sensitivity to drilling activities, but responded differently to the type of environmental perturbations. For instance, macrofauna was most affected by hypoxia at both well-heads (WHs), whereas sediment grain size drove considerable shifts in foraminiferal assemblages between WHs. Moreover, we identified 8 foraminiferal operational taxonomic units (OTUs) that could be indicative of environmental changes. Overall, foraminiferal-metabarcoding proved to be useful at providing complementary information on ecological impacts and at identifying responsible stressors.

MORKEL ZAAYMAN was recently awarded a University of Canterbury departmental travel fund and the Claude McCarthy fellowship to assist in financing his travels to Poland to attend the biennial International Water Association (IWA) conference in Gdansk. It is a specialist conference focusing on the use of wetland systems for pollution control, where, he presented his current research on the removal of personal care products and other emerging organic contaminants in the dissolved phase of wastewater using constructed wetlands and carbonaceous bioreactors.

As the conference had a strong focus on disseminating current research to authorities and to encourage cooperation and collaboration between researchers and the wider community, this was a valuable opportunity for him to represent University of Canterbury, CIBR, and New Zealand science as a whole.

It was also a fantastic opportunity to network with an international science community and top researchers in his field, and make new connections to stimulate future collaborative work and encourage future research and employment opportunities.

TAPU AND NOA – MĀORI CULTURAL VALUES SUPPORTING BIOWASTE MANAGEMENT IN NEW ZEALAND

James Ataria, Virginia Baker, Joanna Goven, Lisa Langer and Alan Leckie.

In New Zealand the management of human waste such as sewage has historically been very poor at incorporating Māori cultural values and experiences. In part this is due to inequitable power structures that were barriers to full and effective Māori engagement in the management of these wastes. A lack of appreciation and awareness of how these cultural values and experiences could usefully contribute to the management of these wastes is another. It has been the latter aspect that has interested CIBR social and cultural researchers who have led a closer examination of how two cultural values, tapu and noa, can inform contemporary biosolids (treated sewage sludge) management.

Tapu and noa are terms that dominate historical records and contemporary discussion especially in reference to the disposal and management of human waste. Notwithstanding the local variation in understanding and interpretation of these two values, tapu is often understood to mean forbidden or restricted, and noa ordinary or free from restriction. Traditionally these were two key cultural concepts that permeated and shaped Māori societal responses and action, and they continue to influence and inform present Māori praxis and thinking today – including biosolids management. Traditional management of human waste effluent was highly prescriptive.

Processes and procedures were nested within cultural values (like tapu and noa) and ethics (tikanga/ritenga) that in turn were influenced by local context and circumstance. The tapu and noa constructs manifest in relation to other values to shape appropriate human behaviour, relationships, and responses to the environment and between individuals at any point in time and for any issues. Therefore, tapu and noa should never be considered in isolation. Further, tapu and noa are not fixed in time but rather transitive; they can be temporary, or more permanent actions, and can oscillate between both ends of the tapu or noa spectrum to manage and respond to changing events and environments.

These frameworks influence how people use an object or resource. This has interesting implications for the management of biosolids--in particular, whether there are certain management conditions that could influence the cultural state of biosolids, that if satisfied would move this waste from a tapu state to a noa state. But how cultural values are interpreted at any place in New Zealand will differ according to local interpretation and history, and therefore it is important that mana whenua (the relevant Māori group for that location) are integral to the decision-making processes (Figure 1).

Māori cultural values like tapu and noa are influenced by different forces or trajectories that influence how they may be expressed in response to issue like biosolids management (e.g., erosion of traditional constructs and power base; place-based dynamics; community demographic (rural or urban); and the evolution of governance structures and resources following Treaty settlements) (Figure 1). Understanding how these trajectories influence a particular local setting will guide the most appropriate engagement approaches and assist with managing expectations between entities. However, at the basis of this engagement should be an intent of building an equitable relationship that will support meaningful and ongoing conversations.

Our research has consistently shown that Iwi organisations do not support a 'flush and forget' approach that can be typical of ratepayer responses to the issue. Iwi, land trustees, hapū and Māori business owners tend to be very keen to engage with local government on waste and biowaste management issues.

In summary Māori values like tapu and noa could play a significant role in localised environmental management decision-making in New Zealand. A millennia of association between Māori and the environment has created sophisticated local knowledge frameworks. Establishing partnerships built on relationships that are supportive

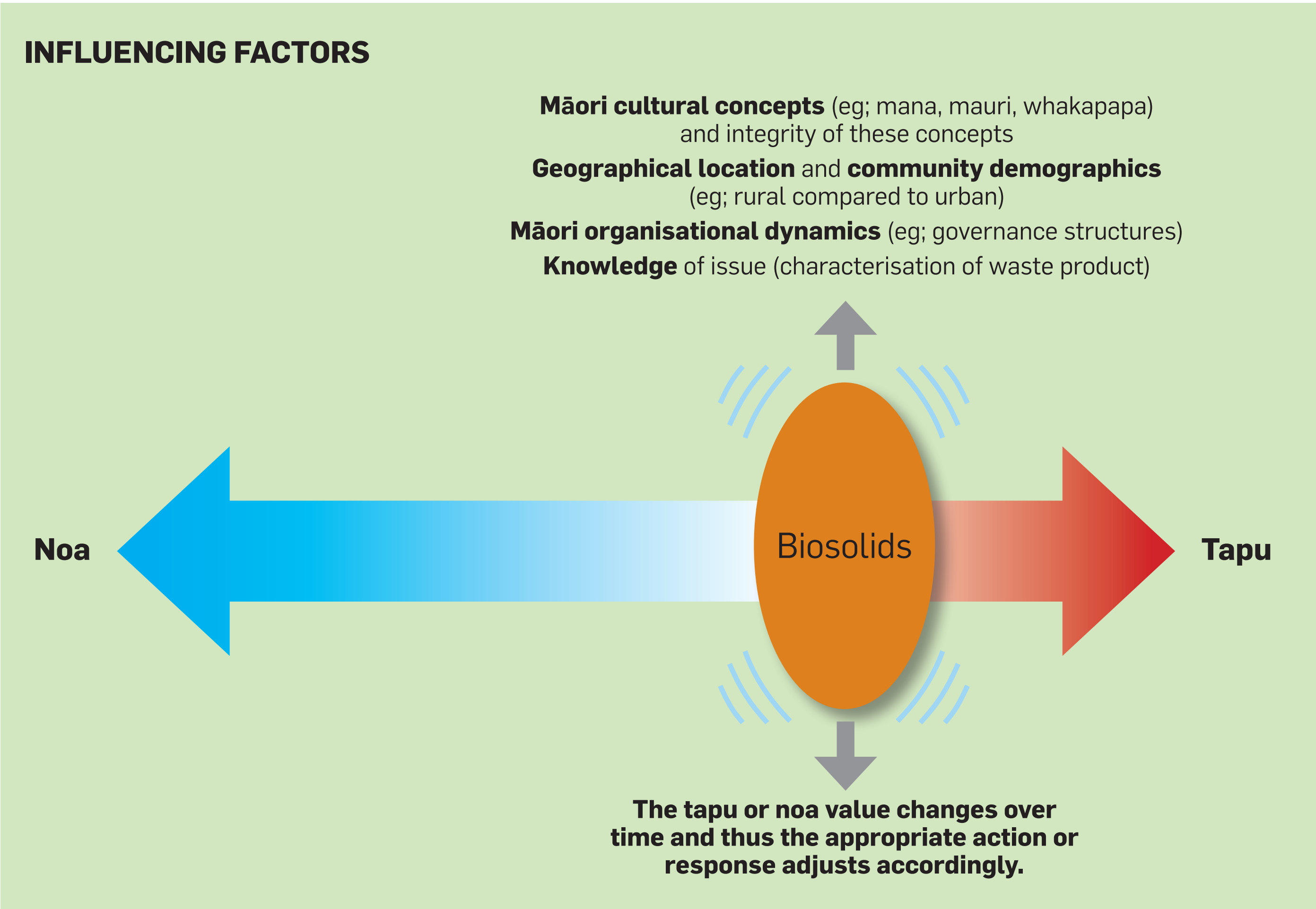

Figure 1. The tapu to noa spectrum and examples of modulating factors that influence the ultimate expression of these values as they pertain to biosolids.

Photograph courtesy of Te Rūnunga o Ngāi Tahu.

of incorporating Māori cultural knowledge will create a conduit best suited to explore how this significant knowledge contribution could occur. CIBR's social and cultural researchers will continue to traverse this landscape with an increasing focus on traditional values and the underlying thinking and philosophies.

Note: The CIBR Social and Cultural team has written a document on tapu and noa that is designed to support local government staff and engineers in better understanding and incorporating Māori worldviews into biowaste management negotiations and solutions.

A greater awareness and deeper understanding of cultural values and frameworks will help support more respectful and meaningful conversations about how to best design and manage local biowaste systems, including biosolids and wastewater discharge impacts. Therefore we promote these frameworks as most ably supporting long-term solutions and co-management approaches for enhanced environmental and biowaste management.

Please contact the newsletter editor for copies of the reports at Sarah.Quaife@esr.cri.nz

MINAKSHI MISHRA – PhD STUDENT

I am a PhD student of soil microbiology at the Department of Soil and Physical Sciences, Lincoln University and my research is being supported by CIBR. I presented my research idea and results obtained during a few conferences this year (including Th3resis and Postgraduate Conference (PG) 2016, Lincoln University). I won Th3resis heats and 1st place during the PG conference. I started my research to find a way to reduce the pathogen load of biowaste to reuse as fertiliser. However, initial results have shown that this research could provide answers to protect our waterways, by preventing contamination and outbreak situations, which recently happened in Havelock North, Hawkes Bay. It feels great to know that people are excited about the prospect of waste being recycled and their excitement is reflected by nearly 25 minutes of question-answer session during my presentation, which is quite unusual.

With my research I am trying to bring a two way benefit for NZ, by using the high nutrient quality of human and animal waste, which can be of concern with poor management, to grow two NZ native and economically beneficial plants, Mānuka *(Leptospermum scoparium)* and Kānuka *(Kunzea robusta)*, and, to use the specific antimicrobial properties of these plants to reduce their pathogen load. So far my results support previous work conducted by Prosser *et al*, 2014, and I believe my final results will highlight the potential to use these plants as a barrier between the freshwater system and increasing human

and animal waste streams. I will be presenting my results at the next waterways conference this year to inform people of the extent of this research and the positive aspects of their waste.

Minakshi Mishra

CIBR EDUCATION OUTREACH

By Sarah Quaife

Students are taught the Up the Pipe Programme. What goes down your drain? And how can we make changes at home to help lessen the burden on the environment?

The CIBR team have been busy with educational outreaches aimed at extending science and science practice to young students and teachers. Early in June, ESR staff attended the Tawa College career expo and the Lower Hutt STEMM festival. The former was aimed at an intermediate schooling level to discuss future career pathways, the environmental problems facing NZ and current research in these fields. The latter aimed to arm those in teaching across all levels with the tools developed by CIBR to discuss science techniques while also addressing the real-world problem of waste. Both events were highly successful and CIBR hope to attend these same events next year.

In addition, ESR staff also hosted students from Windley School and The Spirit of Rangatahi Senior leadership programme to present the Up the Pipe Programme. The programme had to be adapted across different age-groups from intermediate level to a more senior level. This was a great opportunity for CIBR to extend their research into the community and to ask questions that touched on the implications of social behaviour change. Students were asked: what is waste, what kind of products enter our waste stream, and, how can we minimise our impact on the environment just by changing behaviours at home?

We have had feedback that our programme was well-received by students and this in turn has prompted other school's to approach CIBR for further outreach initiatives. As part of this, students from Whitireia Polytechnic and Northcross intermediate school were also hosted at ESR to discuss science pathways. This day was hosted by CIBR where our work was presented as part of discussions and real-world examples of daily research conducted at a crown research institute.

CIBR also hosted a teacher's forum at ESR which discussed pathways for getting science into the classroom in which our Up the Pipe programme and resources were presented as part of discussions. Our resources had a great reception; however, it has also been communicated that teacher's would like for us to go into school's to teach the programme ourselves. We are always on the lookout for funding for this initiative so if you have any ideas for future collaboration or funding opportunities please don't hesitate to get in touch with the CIBR team.

FAREWELL TO STACI BOYTE – TECHNICIAN ESR

There have been some big projects happening within the ESR team of CIBR over the last 18 months (see issues no: 10, 11, and 12 of the CIBR newsletter) and Staci has been instrumental at getting these off the ground and running smoothly. She has never shied away from getting her hands dirty and her sunny smile has made any hurdles that much easier to leap.

CIBR wishes Staci all the best and we hope to be working in collaboration with her again soon.

What's a little poo to dampen one's spirits when the sun is out and you've got snazzy white overalls to boot?

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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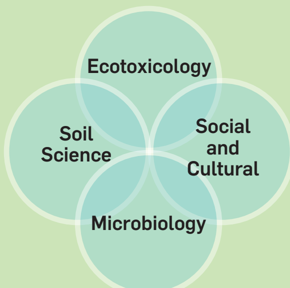

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