Putting waste to work

BIOSOLIDS RESEARCH IN NEW ZEALAND – WHAT’S NEW?

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Centre for Integrated Biowaste Research
Centre for Integrated Biowaste Research (CIBR)

- Integration of two biosolids research programmes (ESR and SCION) to create a more cohesive research effort
- Collaborative Centre with 8 research partners
- Underpinned by Government funding
- Over 15 years working with Biowaste
- Aim: to improve the management of biowaste in New Zealand
Waste management is crucial to our ability to live sustainably

- **Biowaste** - organic, biodegradable waste, includes sewage sludge, organic industrial waste; agricultural waste; kitchen/food waste; and green waste.
- New Zealand produces nearly 700,000 tonnes of biowaste each year.
  That’s approx. 2000 747’s!
- Currently 62% of organic waste goes to landfill
So what’s blocking the path to greater biowaste re-use?

- Alternative solutions are not simple.
- Biowastes can contain micro-contaminants (e.g. heavy metals, pharmaceuticals and pathogens).
- NZ’s unique social and cultural considerations
- Small communities face the extra challenges: low volumes of wastes = low-cost, low-tech solution.
Fundamental to CIBR’s work is the involvement of communities to explore the important social, cultural and economic factors associated with biowaste re-use options.

Grounding of the research in “live case-studies” to ensure that solutions are appropriate for real communities.

Team leader: Lisa Langer, SCION
The Kaikōura Case study

• Small community (approx. 3500, tourist population of up to one million)
• EarthCheck certified - strong commitment to sustainability
• Sludge dredged from WWTP pond and stockpiled
• 1500 tonnes weathered and stabilised – “biosolids”
• Landfill costs: approx. $300,000
• $120 one off payment to rates
Kaikōura community engagement – the Gold standard

- Hui October 2009 - initial engagement
- Face to face interviews
- Hui February 2011 – 19 potential reuse options
  - 5 preferred options
- Hui December 2011 - life cycle and economics
- Kaikōura hui March 2012 - wider community
  - recommended reuse preferences to Council.
Kaikōura biosolids characteristics

- High levels of carbon & plant available nutrients
- *Escherichia coli* low & *Salmonella* not detected
- Very low concentrations of pharmaceuticals
- No acute toxicity to earthworms
- Elevated copper and zinc
- Slightly elevated cadmium & mercury
- Low risk of heavy metal contamination
- Grade ‘Bb': suitable as soil amendment for native and exotic trees/shrubs.
Community preferences

- No biosolids in food chain
- Application of biosolids to exotic forest plantations most favoured – least expensive and completed in few weeks
- Composting and vermicomposting favoured for further investigation
- Rehabilitation of native plantings favoured on small areas
- Farm application not favoured even if outside food chain – minimal land available
- Minimal support for status quo.
The science behind some of the options

- Forest application - long term biosolids field trial – Rabbit Island
- What are the effects of repeated applications on forest growth and nutrition, and the environment?
  - 3 application rates: 0, 300, 600 kg N ha$^{-1}$
## Economic benefits (model predicted)

<table>
<thead>
<tr>
<th>Economic Result</th>
<th>Biosolids Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td>NPV ($/ha, 7% discount rate)</td>
<td>1,927</td>
</tr>
<tr>
<td>IRR (%, excluding land value)</td>
<td>9.61</td>
</tr>
<tr>
<td>IRR (%, land value = $5000/ha)</td>
<td>5.36</td>
</tr>
</tbody>
</table>

**net present value (NPV), internal rate of return (IRR)**
Vermicomposting - a solution for small communities??

- low cost
- potential for cost recovery
- relatively simple
- easily maintained
- culturally acceptable
- safe
Vermicomposting of biosolids

- Improved nutritional value of soil
  - (30% increase in nitrogen & 24% increase in phosphorus)
- Stabilised some heavy metals
  - (reduced arsenic, cadmium, copper, nickel & zinc levels)
- Increased soil carbon and water holding capacity
Biosolids and vermicomposted biosolids increased seedling growth & root mycorrhizal colonization

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Root Colonization (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No biosolids</td>
<td>15-20%</td>
</tr>
<tr>
<td>Biosolids</td>
<td>35-40%</td>
</tr>
<tr>
<td>Vermicompost</td>
<td>70-80%</td>
</tr>
</tbody>
</table>
Vermicomposting - lessons learnt

• Good solution for small communities
• Transition of human waste from tapu to noa
• Can improve quality of biosolids
  – Grade B → Grade A
  – Improved soil fertilizer (compost)
• BUT – a note of caution
For some biowastes (e.g. septic tank), process may not eliminate pathogens

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>NZWWA Guideline Limits Grade A</th>
<th>Final Products (Compost &amp; Vermicompost)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Negative Control 187 days Positive Control 117 days High Septic Tank 131 days Low Septic Tank 131 days</td>
</tr>
<tr>
<td>E.coli</td>
<td>&lt;100 MPN/ g</td>
<td>4 – 14 ND ND – 14 ND – 33</td>
</tr>
<tr>
<td>Salmonella spp</td>
<td>&lt;1 / 25 g</td>
<td>ND ND ND ND – 5.3</td>
</tr>
<tr>
<td>Campylobacter spp</td>
<td>&lt;1 / 25 g</td>
<td>ND &gt;28000 &gt;28000 &gt;28000</td>
</tr>
<tr>
<td>Helminth Ova</td>
<td>&lt;1 / 4 g</td>
<td>ND - 28 120 - 870 60 – 250 84 – 250</td>
</tr>
</tbody>
</table>

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It’s really important to look for more than just *E. coli*

- *E. coli* is a rubbish indicator, important to measure pathogens (e.g. Campylobacter).
- For some wastes a further treatment step might be required (e.g. pre-pasteurisation or further composting) to produce a vermicompost that is safe to be handled.
Tools such as LCA can be a game changer for many in the community.
Kaikōura: preferred re-use options

• Further stabilisation
  – Open air composting
  – Vermicomposting
• Land application
  – Farm application outside food chain
  – Exotic forest application
  – Area with native plantings.

Best practice framework to guide councils and communities to adopt sustainable re-use solutions.
Mitigating environmental contamination

- Biosolids contain micro nutrients
- Can became contaminantants if present at high concs.
  - N and P
  - heavy metals such as Zn and Cu
  - organics (e.g. pharmaceuticals and medicines)
  - pathogens
- Some contaminants are industrial, legislation/guidelines to reduce (e.g. heavy metals such as zinc and copper)
- BUT – the source of many contaminants are domestic – not easily reduced
So what are the big knowledge gaps?

• Which new and emerging contaminants are of most concern?
• Biowastes can contain a complex cocktail of contaminants - environmental fate and effects and how they may interact unknown
The “new PCBs”

• Organics in many guidelines are historical contaminants - not in current use, environmental concentrations are low, represent background.

• WERF/US EPA – identified priority organic chemicals used in high production volume (e.g. plasticizers, phthalates, detergents, fragrances, antimicrobial compounds and parabens)

• Wide spread use, multiple products, levels in the environment are increasing: The “New PCBs”
Ecotoxicology and environmental chemistry

• Collating data on concentrations of “emerging organic chemicals’ in biowastes.

• Using a variety of ecotox assays:
  – Cell bioassays, bacteria, algae, spring tails, earthworms, zebra fish, whole soil systems

• A short list of contaminants which constitute the greatest potential ‘risk’

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Team leader: Louis Tremblay, Cawthron Institute
# Toxicity of commonly used chemicals using algal test

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Function</th>
<th>IC$_{50-96hr}$ (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzophenone</td>
<td>UV protection</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>2-Phenoxyethanol</td>
<td>Antibacterial</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>2-Phenylphenol</td>
<td>Disinfectant</td>
<td>n/a</td>
</tr>
<tr>
<td>DEET</td>
<td>Insect repellent</td>
<td>[10 – 100] (41)</td>
</tr>
<tr>
<td>Octyl methoxycinnamate</td>
<td>Sunblock</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>4-Methylbenzylidene camphor</td>
<td>Sunblock</td>
<td>n/a</td>
</tr>
<tr>
<td>Chloroxylenol</td>
<td>Disinfectant</td>
<td>0.6 (0.4 - 0.8)</td>
</tr>
<tr>
<td>Gemfibrozil</td>
<td>Lipid regulator</td>
<td>[100 – 1000]</td>
</tr>
<tr>
<td>Diclofenac sodium salt</td>
<td>Anti-inflammatory drug</td>
<td>32.8 (26.2 – 51.1)</td>
</tr>
<tr>
<td>Triclosan</td>
<td>Antibacterial</td>
<td>&lt; 0.003</td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>Plasticiser</td>
<td>6.85 (5.78-7.65)</td>
</tr>
</tbody>
</table>
Inhibition of light production from lux-gene modified *Escherichia coli*

Can calculate the concentration of pollutant that causes a 50% decline in activity (light output)

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Olivier Champeau, Cawthron
Soil microbes are sensitive to triclosan

Triclosan directly impacted microbial numbers in the soil

EC\textsubscript{50} = 803ppm
EC\textsubscript{20} = 195 ppm
EC\textsubscript{10} = 85 ppm
What does all this mean?

• Prioritised chemicals identified and can be ranked:
  – Triclosan > Carbamazepine > Bisphenol A

• But what happens when we mix them together????
Triclosan + metals = impacts on soil health and function

As Cu increases, soil microbes don’t seem to be able to degrade TCS - reduction in both transformation and degradation of TCS.

Cu + TCS = more toxic

50 ppm triclosan

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Smart assays such as PICT (Pollution induced community tolerance)

- A tool to detect the effects of potential pollutants well before gross impacts.
- Respiration based assay, measures soil community utilization of different food types.
- \( \text{Cu} + \text{triclosan} = \text{lower EC}_{50} \) than the control treatment.
- Soil microbial communities were not able to cope with a combination of both triclosan and copper as well as they would when exposed to either of them alone.
Outcomes

• Starting to build up a picture of which chemicals are most toxic.

• Outcome:
  – ensure that guidelines and policy target contaminants of most concern, including identifying when combinations can have a synergistic impact (1+1=3).
  – ways to manipulate the system so environmental impacts are minimized.
Manipulating the system: reducing nitrate leaching into water ways
Using amendments to control nutrient leaching

- Should inhibit mineralisation or nitrification, or promote immobilisation
- Should be readily available, low cost and not reduce soil fertility
Some biochars eliminate nitrate leaching.
Biochar + biosolids promotes pasture growth

The graph shows the average dry biomass (g/pot) for different treatments:
- Control
- 2% biosolids
- 2% biochar

The data indicates that the combination of biochar and biosolids leads to the highest average dry biomass, indicated by letter A. The control group shows the lowest biomass, indicated by letter C.
Conclusions

• The integration of environmental, cultural, social science can give decision-makers and their communities frameworks to balance environmental, economic, social and cultural factors to increase sustainable waste management – especially of the more contentious wastes like biosolids!

• Methodology can provide a basis for regional land use planning, national guidelines and policy directions.
Acknowledgements

• Thank you to our Mokai and Kaikōura case study communities and The Advisory Group for their invaluable contribution to this research programme.

• Ministry of Business, Innovation and Employment (MBIE) for funding this research programme.