Biosolids: A New Zealand perspective

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Biosolids: A New Zealand perspective

Biowaste is an unavoidable end product of human communities - raw sewage.

Sludge is the residue remaining after raw sewage is processed.

Biosolids are the organic materials remaining after sludge is treated. They can contain bio-nutrients, and also microbiological and chemical contaminants, pharmaceuticals, parasites, radioactive material, heavy metals, nano-particulates, and other contaminants.

The treatment of wastewater and sewage - and the management of the biosolids that treatment produces - are issues of concern related to disease and environmental pollution. Because of the enormous volume of material involved and the difficulties associated with disposal, there is pressure to utilize the perceived benefits on a greater scale.

Biosolids are routinely dispersed on land in New Zealand. For example:

- **Nelson** Council has applied biosolids since 1996 on the 1000 ha forestry plantation, Rabbit Island (Moturoa). A higher tree growth rate has been recorded since 1996.[1]

- **New Plymouth**'s Treatment Plant produces Bioboost[2], a fertiliser sold for residential and commercial use that is made from treated sewage sludge.

- **Thames/Coromandel** District Council's Biosolids Management Strategy claims composting is an economic method for it to deal with biosolids. However, biosolids composting operations ceased in 2014.[3]

Among other countries, the US, Europe and Australia put around 40 per cent of treated biosolids on agricultural land, whereas New Zealand puts 90 percent into landfills.[4] The application of biosolids to land is a contentious issue and the methane gas produced by sludge in landfills is inconsistent with New Zealand's commitments to the Kyoto Protocol.[5]

New Zealand regulations direct that untreated sewage may not be discharged within 500 metres from land, or in water less than five metres deep. Fewer restrictions apply to treated sewage. Sewage discharge is prohibited near marine farms, mataitai (traditional food collection) reserves or marine reserves.[6]

During heavy rainfall sewage is discharged occasionally into the ocean approximately 1.8km from shore off Moa Point, Wellington.[7] At Christchurch, after processing through oxidation ponds, cleaned water is discharged from a pipe 3 km off New Brighton beach; the pipe being 5.2 km long, 1.8m wide, and buried about 8m below the sea floor.[8]

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[1] http://www.nzjf.org/free_issues/NZJF54_2_2009/2FF0C559-23C0-4c78-ABA6-E2DD6EE34047.pdf.
[2] http://www.bioboost.co.nz/How-It-Is-Made. Safety Data Sheet http://www.bioboost.co.nz/Portals/0/pdfs/BiosolidsSafetyDataSheet.pdf
[3] http://www.tcdc.govt.nz/Your-Council/Council-Projects/Current-Projects/Biosolids-Compost-Project/
[4] Should we put biowaste on our agricultural land? 12 October 2009. http://www.sciencemediacentre.co.nz/2009/10/12/should-we-put-biowaste-on-our-agricultural-land/
[5] http://unfccc.int/kyoto_protocol/items/2830.php
[6] http://www.maritimenz.govt.nz/Environmental/Sewage-discharge/Sewage-discharge.asp
[7] http://wellington.govt.nz/services/environment-and-waste/sewerage-and-wastewater/sewage-discharges/about-sewage-discharges. Map http://wellington.govt.nz/~/media/services/environment-and-waste/sewerage-and-wastewater/files/discharge-map.pdf
[8] http://www.ccc.govt.nz/homeliving/wastewater/treatmentplant/chchwastewatertreatmentplant/index.aspx#jumplink9

Guidelines for land application of biosolids

The conversion of sewage sludge into biosolids and the controlled application of biosolids to land are perceived to offer the advantage of the fertilising and soil conditioning properties of a resource that presents huge disposal problems and which is a sustainable resource. The 'Guidelines for the safe application of biosolids to land in New Zealand'[9] acknowledges that protecting and enhancing the quality of the environment is essential for sustainable development:

> *"Biosolids have valuable fertilising and soil conditioning properties. They contain micronutrients and organic material and, worldwide, they are commonly applied to land as a means of restoring degraded soils or boosting the productivity of soils within areas of low natural fertility. Examples of beneficial use include the restoration of depleted cropping soils, maintenance or enhancement of soil fertility in forests, rehabilitation of mine tailings and quarry sites, landfill cover, golf courses, parks and gardens."*

The Guidelines also confirm biosolids contain microbiological and chemical contaminants that give legitimate concerns about public health, environmental and economic risks and includes a review of pathogens in New Zealand conditions, concluding directions that testing should be carried out for E. coli, campylobacter, salmonella, enteric virus, and helminth ova. However, the Guidelines are silent on the testing for a number of chemicals that have been found in wastewater, sewage sludge and biosolids around the world.

The Guidelines provide a biosolids grading system that is made up of two parts. The first part, which is denoted by a capital 'A' or 'B', represents the stabilisation (microbiological) grade. The second part, denoted by a lower case 'a' or 'b', represents the chemical contaminant grade. The Guidelines recommend that regular audits be commissioned to ensure top quality 'A' biosolids continue to meet requirements. Biosolids which fall short of an 'Aa' standard - for example, where contamination exceeds specified limits - can still be dumped if granted resource consent. Class 'B' biosolids would potentially contain pathogens at levels constituting a risk to human health. According to the Guidelines, additional protections in the 'A' grade may include a requirement that treated land cannot be used "directly" for residential activities and biosolids applied to land must not:

- Run off into water or contaminate streams;
- Occur on wahi tapu or sacred Maori sites;
- Create offensive smells;
- Be within 20m of property boundaries, water bores, geothermal and coastal marine areas.

[9] https://www.waternz.org.nz/Folder?Action=View%20File&Folder_id=101&File=biosolids_guidelines.pdf

Recommended controls for stabilisation of Grade B biosolids would depend on end use; for example, fodder crops; food crops for human consumption that may be eaten unpeeled or uncooked; public amenities; land reclamation; pasture, orchards and turf farming.

The following table illustrates the Grading system.[9]

Table 1: The Grading system in the Guidelines for the safe application of biosolids to land in New Zealand (NZWWA, 2003)

Grade 'Aa'	'Aa' grade biosolids have substantially reduced pathogen contaminants, such that the product is deemed safe to be handled by the public with minimal risk.
Grade 'Bb'	Grade 'Bb' biosolids can have a lower level of treatment and may contain pathogens. Use is restricted and subject to 'best practice' management to protect the soil and waterways.

Consent for disposing of biosolids may require the listing of the level of each of the contaminants specified in the Guidelines. Analysis must meet established criteria. However, this is only relevant for those contaminants listed in the guidelines; there are many contaminants that are simply not measured. New Zealand is well equipped with analytical laboratories to provide complete, accurate and unambiguous reports.

This raises the question of duty of care - a legal obligation to exercise a reasonable standard of care to protect from unnecessary risk of harm and should govern any application of biosolids onto land that will grow food intended for human or animal consumption. The official recognition is that biosolids should not be applied at a rate that results in soil contaminant limits being reached after one or two applications, and applications should not cause contaminant limits to be reached for at least a 20-year application period.

From a human and environmental safety perspective, these contaminants should not be added to agricultural soils or any soils that may be used for growing food under any circumstances. Many of them are persistent organic pollutants (POPs): organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. POPs have been observed to persist in the environment, to be capable of long-range transport, to bio-accumulate in human and animal tissue, to bio-accumulate in food chains, and to have potential significant impacts on human health and the environment. Governments appear to see only an economical way to get rid of biosolids, especially good if businesses can make money from it.[10]
The Stockholm Convention on Persistent Organic Pollutants, an international environmental treaty signed in 2001 and effective from May 2004, aims to eliminate or restrict the production and use of persistent organic pollutants.[11]

Consistent with the generally accepted 'official' premise that there is little or no potential for adverse effects using biosolids in the ways mentioned, under a "permitted activity rule" there is therefore no requirement to monitor the effects of any discharge on land.

[10] Ritter L; Solomon KR; Forget J; Stemeroff M; O'Leary C. "Persistent organic pollutants". United Nations Environment Programme. Retrieved 2007-09-16.
[11] http://en.wikipedia.org/wiki/Stockholm_Convention_on_Persistent_Organic_Pollutants

Methods for processing biosolids

There are many pathogens potentially present in biosolids and the hazards presented vary. After processing under a certified quality assurance system, biosolids should be essentially free of pathogens. Many methods are used to achieve this, including the following:

Anaerobic digestion – sludge put in oxygen-free closed tanks, with or without mechanical mixing or heating, reduces volatile solids that reduce potential pathogen regrowth after treatment.

Aerobic digestion - sludge in open or closed vessels is agitated or has air injected into it. Heat is generated by bacteria breaking down organic matter to CO_2, nitrate, nitrogen and water.

Pasteurisation - heating sewage sludge to 70–80°C using steam injection or heat exchangers for approximately 30 minutes to reduce the number of pathogens. Pasteurisation is used in conjunction with other processes; e.g. mesophilic digestion by biological action at 27° to 38°C (80° to 100°F).

Irradiation - aims to reduce pathogens by disrupting their cell content to destroy the organism or prevent it reproducing. With gamma or beta ray-based irradiation effectiveness relates to the length of dose applied to the sludge. This method is not currently used in New Zealand.

Lime stabilisation - effectiveness relates to the time at over pH 12 to destroy or inhibit pathogens. This method produces odours if the pH falls below 10.5. Protozoan cysts may be inactivated, but lime may not be effective on helminth ova, unless combined with heat.[12]

Composting - an aerobic process treating sludge mixed with a co-product; e.g. sawdust, green waste, wood chips. The end product provides a source of carbon, increases porosity and oxygen flow, and absorbs moisture. Heat generated by aerobic biological activity destroys pathogens.

Thermal and air drying – sludge is dried naturally on sand or gravel beds allowing biological decomposition and ammonia formation. Moisture loss reduces bacteria, protozoa and viruses.

Any one or more of the above methods or other methods can be used. For example, around 5000 dry tonnes of biosolids are produced from the Christchurch Wastewater Treatment Plant each year, and these go through several processes. Solid Energy NZ reuses the end product to rehabilitate mined areas at the Stockton mine site.[13] Rotorua District Council is trialling a ‘thermal deconstruction’ process developed by Scion to ‘cook’ biosolids into reusable nutrients and chemicals. It is said the methane produced can aid electricity production.[14]

Here are some other ways that have been suggested to dispose of biosolids:

[12] USEPA, 1999
[13] http://www.ccc.govt.nz/homeliving/wastewater/treatmentplant/chchwastewatertreatmentplant/biosolids.aspx
http://www.coalnz.com/publications-and-resources/fact-sheets/stockton-opencast-mine.pdf
[14] http://www.sciencelearn.org.nz/News-Events/Latest-News/News-Archive/2010-News-archive/Gaining-value-from-biosolids

- Land reclamation of exhausted gravel pits and coal mines;
- Landfill as a component of topsoil;
- Lime stabilized biosolids to mitigate acid;
- Mine drainage, remediation or bioremediation with compost or iron-rich biosolids of urban/suburban contaminated sites;
- Restoration and development of water features such as wetland establishment or enhancement, or shoreline restoration;
- Horticulture and landscaping;
- Compost and potting mixes, and fertilizers such as heat-dried pellet fertilizer;
- Sod production for lawns, parks, sports fields, green roofs;
- Erosion control such as compost berms;
- Treatment for roadside re-vegetation;
- Forest and reforestation fertilization;
- Industrial use in cement kilns making brick or other building materials;
- Making glass aggregate for use in pavements.

Resources can potentially be recovered from biosolids, including:

- Minerals and metals;
- Bio-energy (green energy) from digestion in digesters[15];
- Incineration to provide thermal oxidation or thermal conversion;
- Electricity generation[16];
- Gasification;
- Pyrolysis and other developing hi-tech energy production options.

"Public health protection is a major issue in the use of biosolids"[9]

A survey by the US Environmental Protection Agency (EPA) showed biosolids contain a wide range of mutagenic and neurotoxic chemicals present at a "million-fold higher" concentrations compared with their levels in polluted air and water; that is, in parts per *million* (ppm) as opposed to parts per *trillion* (ppt).[17] [18]

Sewage sludge and thence biosolids can contain diverse compounds in diverse measurements depending on the origin of the sludge; domestic or industrial. Sewage sludge may contain numerous chemicals and compounds, some of which are carcinogenic, mutagenic, genotoxic, immunotoxins, endocrine disruptors, or reproductive and developmental toxins. Many of these chemicals are capable of crossing the placenta to reach the unborn foetus, and many also bioaccumulate. They can include:

- Pesticides;
- Heavy metals[19];
- Polychlorinated biphenyls (PCBs);

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[15] http://www.renewableenergyworld.com/rea/news/article/2010/12/managing-biosolids-and-generating-green-energy
[16] http://www.wef.org/uploadedFiles/Biosolids/Biosolids_Resources/Newsletter/Newsletter_PDFs/Potential%20 Power%20of%20Renewable%20Energy%20Generation.pdf
[17] 'Biosolids: Targeted National Sewage Sludge Survey', 2009, 822-R-08-014 www.epa.gov/waterscience/biosolids/tnsss-tech.pdf
[18] http://water.epa.gov/scitech/wastetech/biosolids/upload/factsheet2009_review.pdf
[19] Chemical Fractionation of Trace Elements in Biosolid-Amended Soils and Correlation with Trace Elements in Crop Tissue, Shober et al, http://ecosystems.psu.edu/research/labs/environmental-soils/publications/trace-element-fractionation-and-crop-uptake-correlation-in-soils-receiving-biosolids

- Phthalates incorporated into plastics as plasticisers; phthalates and nonylphenol are present in relatively high levels in sludge;
- PAHs (polycyclic aromatic hydrocarbons), ;
- Surfactants, substances used to reduce the surface tension of a liquid in which they are dissolved;
- Chemicals in domestic washing detergents and surface cleaners are used in high amounts and go directly into water[20];
- Chemical wastes;
- Heavy metals, including chromium, lead, and mercury;
- Polybrominated diphenyl ether congeners and other brominated flame retardants, perfluorinated compounds, dioxins and furans[21];
- Common prescription pharmaceuticals, including hormonal agents;
- Radioactive material from the urine of patients receiving chemotherapy;
- Pathogenic agents[22].

Areas of concern related to applying biosolids on land include:

1. Pathogenic agents

Pathogens are disease-causing microorganisms that include bacteria, viruses, protozoa, and parasitic worms. Potentially, they are a public health hazard:

- if transferred to food crops grown on land to which biosolids are applied;
- where they reach runoff to surface waters from land application sites; and
- where they are carried from a site by vectors, e.g. insects, rodents, and birds.

Bacteria causing food poisoning are being discovered increasingly in fresh produce. How pathogens get inside plants is not fully understood. One hypothesis proposes plants are contaminated when grown in fields fertilized with inadequately treated manure. This has serious implications for the application of biosolids to land designated to grow food crops.[23]

Pathogens in sludge can cause disease in humans, animals and plants, and are also referred to as Bacillus, Bacillus coli, colon bacteria, Coliform, Faecal coliform, Enteric bacteria, Etiologic agents, infectious agents, infectious organisms, disease-producing agents.[24]

Coliform and faecal coliform refer specifically to certain bacteria that ferment lactose to produce gas and/or acid within 24-48 hours. E. coli is the primary coliform and faecal coliform. One of the more deadly forms is the genetically engineered E. coli 0157[25] which is in fact neither a coliform nor a faecal coliform as the gene to ferment lactose has been removed.

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[20] http://ec.europa.eu/environment/waste/sludge/pdf/organics_in_sludge.pdf
[21] Environ Sci Technol. 2011 Oct 1;45(19):8015-21. doi: 10.1021/es1039425. Epub 2011 Apr 22, Application of WWTP biosolids and resulting perfluorinated compound contamination of surface and well water in Decatur, Alabama, USA. Lindstrom et al.
[22] http://water.epa.gov/scitech/wastetech/biosolids/upload/2009_01_15_biosolids_tnsss-tech.pdf
[23] Horswell, Ambrose and Speir, ESR, Kenepuru Science Centre, New Zealand http://www.esr.cri.nz/competencies/water/Pages/PathogenContaminantsinLand.aspx
[24] Sewage sludge or biosolids? Jim Bynum, VP and Gail Bynum, PhD 2010. http://thewatchers.us/book/sludge-biosolids.html
[25] 'E. coli 0157:H7 and Genetic Engineering' http://www.i-sis.org.uk/ecoli.php

To put E. coli in general in context, bacteria in the human body respond well biologically at a normal internal temperature of 37.00°C / 98.6°F. If that temperature rises, bacteria become heat stressed due to dehydration. As the temperature approaches 40.5°C / 105°F, the bacteria desiccate and most become dormant. They remain viable although cannot be cultured using standard laboratory methods, with the exception of a few thermo-tolerant E. coli which continue to show limited activity. At 44.50°C / 112.1°F a human would die. Bacteria will repair heat-damaged cells and become highly viable again if the temperature drops and moisture becomes available to them again.[26]

In the US, reported cases of food-borne illnesses have increased since the disposal of sewage sludge on land increased.

- In 1986, EPA documents showed two million food-borne illness cases.
- In 1999, the Centres for Disease Control (CDC) put the number at 76 million with 5000 deaths in 1999 alone.
- Insurance companies have documented an increase of MRSA (methicillin-resistant Staphylococcus aureus) infections; 1900 cases in 1993 to 368,300 in 2005; 18,000 deaths.

Mutant bacteria are created by natural biological mutation and/or horizontal gene transfer (HGT). Accelerated mutation of bacteria in wastewater plants can result from UV disinfection of wastewater, a higher percentage of antibiotic resistant bacteria leaving the plant than entering.[26]

2. Heavy metals

The following test results for heavy metals are included in a Report commissioned by Gisborne District Council, 'Biosolids Treatment and Disposal Options Report', dated 3 June 2005.

Table 1. Estimated metal concentrations for Gisborne using measured concentrations at the existing outfall, versus the biosolids contamination grading system.

Note: 15,000m3/day assumed for average flow at outfall..

Heavy Metal	Load exiting Gisborne Outfall (g/day)	Expected concentration in biosolids cake (mg/kg dry weight)	Grade "a" maximum conc. (mg/kg dry weight)	Grade "b" maximum conc. (mg/kg dry weight)	Median values for anaerobic sludge (mg/kg dry weight)
Cadmium	6	**2**	1	10	**1.8**
Chromium	430	130	600	1500	81
Copper	1020	**300**	100	1250	**418**
Lead	240	75	300	300	87
Mercury	4	**1.2**	1	7.5	**3**
Zinc	2800	**860**	300	1250	**1031**

In the foregoing, to further support the estimated metal concentration that would be encountered for Gisborne, Table 2, which follows, presents metal concentrations found in biosolids of existing New Zealand wastewater treatment plants. All the findings, excluding

[26] M C Meckes, 1982, 43(2):371. Appl. Environ. Microbiol. http://aem.asm.org/content/43/2/371.full.pdf

Thames, have metal concentrations exceeding the ‘A’ grade requirement, the most common being for cadmium, copper, mercury, nickel and zinc. Plants from Christchurch to Mangere (inclusive) use anaerobic digestion. Five of the plants exceed the limit of zinc concentration for a ‘B’ grading.[27]

Table 2. Metal Concentrations in mg/kg Dry Solids for various WWTP around New Zealand (NZWWA, 1998).

	PU	Dunedin	Christchurch	Horowhenua	Hutt (Wianui)	Invercargill	Fielding	North Shora	Tokoroa	Mangere	Carterton	Alexandra	Otaki	Paraparaumu	New Plymouth	Porirua	Rodney	Rotorua	Thames
Arsenic	20	3	18	4	1	13	8	5	10	**25**	9	4	4	6	4	**4**	10	8	4
Cadmium	1	**2**	**4**	**3**	**2**	1	1	**2**	**2**	**2**	**2**	1	**2**	**2**	1	1	**2**	1	1
Chromium	600	90	**1000**	80	40	46	30	93	50	470	50	10	40	35	200	35	40	40	2
Copper	100	**300**	**460**	**650**	**400**	**200**	**160**	**450**	**350**	**480**	**550**	**370**	**250**	**260**	**480**	**360**	**590**	**220**	20
Lead	300	180	200	90	70	140	50	85	90	110	150	38	50	55	60	43	75	60	15
Mercury	1	**2**	**3**	**3**	**7**	**3**	1	**4**	**6**	**3**	**15**	**4**	1	**3**	1	1	**12**	**3**	1
Nickel	60	25	**90**	20	20	30	16	**250**	30	**75**	30	12	7	14	**130**	20	27	23	17
Zinc	300	**600**	**1300**	**1400**	**600**	**670**	**740**	**820**	**1500**	**1300**	**800**	**550**	**600**	**660**	**1860**	**570**	**680**	**1000**	150

Note: column PU contains the metal limits for grade “a”.

Gisborne District Council, Biosolids Treatment and Disposal Options Report 2005
http://www.gdc.govt.nz/assets/Wastewater-Plant/Library/45130-Appendix-18-GDC-Biosolids-Treatment-Disposal-Options.pdf

The predicted ongoing levels of some metals in digested and dewatered solids mean Gisborne solids would likely have a ‘B’ contaminant grade. The metals are copper (from water pipes and cylinders), zinc (from personal products and the water supply system), possibly mercury (from amalgam fillings in teeth) and cadmium.[8]

Once dispersed, flora can uptake contaminants; for example, Salix (willows) uptake heavy metals.[28] [29] Further, biosolids containing heavy metal concentrations applied to land growing food crops could result in plants taking up and bio-accumulating heavy metals.[30] There are four main pathways by which a contaminant in soil can enter a plant:

- Root uptake from soil solution and subsequent translocation from roots to shoots;
- Absorption by roots or shoots of volatilized organics from the surrounding air (e.g. vapour);
- Uptake by external contamination of shoots by soil and dust, followed by retention in the cuticle or penetration through it; and
- Uptake and transport in oil channels found in some oil-containing plants such as carrots[31].

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[27] http://www.gdc.govt.nz/assets/Wastewater-Plant/Library/45130-Appendix-18-GDC-Biosolids-Treatment-Disposal-Options.pdf

[28] ‘Phytoextraction of heavy metals by willows growing in biosolids under field conditions’, Laidlaw WS et al. www.ncbi.nlm.nih.gov/pubmed/22218182 J Environ Qual. 2012 Jan-Feb;41(1):134-43. doi: 10.2134/jeq2011.0241.

[29] ‘A Review on Heavy Metals (As, Pb, and Hg) Uptake by Plants through Phytoremediation’ Bieby Voijant Tangahu et al, June 2011 http://www.hindawi.com/journals/ijce/2011/939161/

[30] ‘Studies on transfer and bioaccumulation of heavy metals from soil to lettuce’, Smical et al, Env Eng Man J, Sep/Oct 2008, Vol.7, No.5, 609-615 http://omicron.ch.tuiasi.ro/EEMJ/http://omicron.ch.tuiasi.ro/EEMJ/pdfs/vol7/ no5/20_Smical_A.pdf?origin=publication_detail

[31] Carrots can concentrate lipophilic chemicals in their roots because of their lipid content. Carrots showed the highest concentrations, and adsorption of PAHs to the root surface.

Plant uptake occurs, influenced by the soil type and other factors. The surfaces of roots and tubers are especially prone to absorb contaminants from soil.

3. Nano-particles

There will be nano-particles in New Zealand biosolids.[32] Plants uptake nano-particles applied to land growing food crops and can lead to human ingestion of nano-particles of unknown composition or quantity. Plant uptake varies with the plant and the type of nano-material.

Nano-materials can impact on microbes and microbial processes related to nutrient cycling, to plant growth and composition if they are transferred from soil to plants, and to plant–microbe interactions that affect soil fertility.[33]

Metal oxide nano-materials - cesium oxide (CeO2) and zinc oxide (ZnO) – were both found to be taken up by soybean plants growing in farm soil to which the nano-metals were added. The study researchers concluded dispersing biosolids that may contain nano-materials onto food crops could lead to agriculturally associated human and environmental risks from nano-materials.[21] It has also been found that nano-materials formed from cadmium selenide accumulated in Pseudomonas bacteria.[34] The concentration of cadmium increased in a transfer from bacteria to protozoa. The nano-material was substantially intact in the increased concentration, with little degradation.

The fact that the ratio of cadmium and selenide was preserved throughout the study indicated that the nano-material was being concentrated, more or less intact. Because there were toxic effects following the transfer to the protozoa, concern was raised that there could be toxic affects higher up the food chain. This would potentially be a hazard for any form of life.

Environmental and biological effects of nano-particles in biosolids include adverse effects to earthworms, essential to sustaining agriculture and the natural environment. Their activity creates tunnels which let in air and rainwater and improve drainage, and brings nutrients nearer the surface where plants can use them. Earthworms mix leaves, sticks, stones and other material into the soil, and their droppings (casts) are rich in nutrients for plants.[35] One study found Cobalt 60 (C60) nano-particle exposure may seriously affect earthworm populations, juveniles particularly being more sensitive to C60 exposure than adults.[36] Other studies found earthworms are adversely affected by nano-particles of zinc and copper. The effect parameters studied were survival, reproductive output and avoidance behaviour. The

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32 Cawthron Institute Report No. 2667, Risk assessment of emerging contaminants in treated wastewater in the Auckland Region. http://www.watercare.co.nz/SiteCollectionDocuments/AllPDFs/RiskAssessmentofemergingcontaminantsintreatedwastewater.pdf. Waste Management, Volume 30, Issue 3, March 2010, Engineered nanoparticles in wastewater and wastewater sludge – Evidence and impacts. http://www.sciencedirect.com/science/article/pii/S0956053X09004607. Environ Sci Process Impacts, 2013 Jan;15(1):39-48. Impact of metallic and metal oxide nanoparticles on wastewater treatment and anaerobic digestion. http://www.ncbi.nlm.nih.gov/pubmed/24592426

33 Priester, JH et al, 'Soybean susceptibility to manufactured nanomaterials with evidence for food quality and soil fertility interruption', Proceedings of the National Academy of Sciences, 20 August 2012, http://www.pnas.org/content/109/37/E2451/1.

34 Werlin, R et al., 'Biomagnification of cadmium selenide quantum dots in a simple experimental microbial food chain', Nature Nanotechnology, December 2010, www.nature.com/nnano/journal/v6/n1/abs/nnano.2010.251.html

35 http://www.teara.govt.nz/en/earthworms

36 'Effects of C60 nanoparticle exposure on earthworms (Lumbricus rubellus) and implications for population dynamics', van der Ploeg et al, Environ Pollut. 2011 Jan;159(1):198-203. doi: 10.1016/j.envpol.2010.09.003. http://www.ncbi.nlm.nih.gov/pubmed/20932615

results indicated a nano-particle-specific effect - lower reproductive output and higher avoidance.[37]

Toxicological studies on animals and fish have shown adverse effects.[38]

We know nano-particles can pass through epithelial surfaces (skin, gastrointestinal, conjunctiva) and the endothelial barriers lining blood vessels, and can be inhaled and pass through the blood-brain barrier. What has emerged is that there are effects at the cellular level that could potentially adversely affect humans and these effects could depend on the nano-particle base material, its size and structure, and substituent and coating.[39] [40]

What has not been given sufficient scrutiny is research by regulatory bodies responsible for food and environmental safety. Nor has enough attention been given to the handling of nano-waste, e.g. the reduction and treatment of industrial and agricultural wastes and groundwater remediation where waste is seeping into groundwater.

What happens when nano-materials are ground up, incinerated, or disposed of at a transfer station, or released into the atmosphere, water or soil? Studies have shown nano-particles can move in unexpected ways through soil and potentially carry other substances with them.[41] We currently have no way of tracking nano-particles or nano-materials in soil or water. Released into the atmosphere, airborne particulate nano-materials could travel vast distances.[42] The need for applying caution is highlighted by reports such as that published in the European Respiratory Journal study on deaths that occurred after inhalation of nano-particles for a prolonged period and confirmed in autopsies on the victims.[43] While this happened in inadequately ventilated conditions it should sound a cautionary note.

How do we regulate and handle the waste created by nanotechnology safely and effectively? The city of Berkeley in California was the first local body to take action when it adopted a 'manufactured nanoscale material disclosure ordinance'.[44]

Regulators must monitor industrial applications of nanotechnology and subsequent waste, and be cognisant of the nano-materials in use in New Zealand: dental fillings; cleaning materials; non-stick, protective applications on glass; personal care products; veterinarian and pharmaceutical products; food additives and packaging; and more.

Research and regulations based on independent studies are urgently needed.

4. Irradiation effects

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[37] 'Toxicity of zinc oxide nanoparticles in the earthworm, Eisenia fetida and subcellular fractionation of Zn', Li et al, Environ Int. 2011 Aug;37(6):1098-104. doi: 10.1016/j.envint.2011.01.008. http://www.ncbi.nlm.nih.gov/pubmed/21402408. 'Toxicity of copper nanoparticles and CuCl2 salt to Enchytraeus albidus worms: survival, reproduction and avoidance responses', Amorim and Scott-Fordsmand, Environ Pollut. 2012 May;164:164-8. doi: 10.1016/j.envpol.2012.01.015. http://www.ncbi.nlm.nih.gov/pubmed/22361055

[38] https://ore.exeter.ac.uk/repository/handle/10036/93696, 'Uptake and Effects of Nanoparticles in Fish, University of Exeter

[39] 'Impact of Gold Nanoparticle Concentration on their Cellular Uptake by MC3T3-E1 Mouse Osteoblastic Cells as Analyzed by Transmission Electron Microscopy', Thikra Mustafa et al, 2011,http://omicsonline.org/2157-7439/2157-7439-2-118.php

[40] 'Influence of nanoparticles on blood-brain barrier permeability and brain edema formation in rats', Sharma et al, Acta Neurochir Suppl. 2010;106:359-64. doi: 10.1007/978-3-211-98811-4_65. http://www.ncbi.nlm.nih.gov/pubmed/19812977

[41] http://copublications.greenfacts.org/en/nanotechnologies/l-2/6-ealth-effects-nanoparticles.htm

[42] Organic NZ 'Nanotechnology: Safe or not?' Sep/Oct 2010; 'Nano waste: How do we deal with it?' Nov/Dec 2010.

[43] Exposure to nanoparticles is related to pleural effusion, pulmonary fibrosis and granuloma', Song Y et al., European Respiratory Journal, September 2009, erj.ersjournals.com/content/34/3/559.short.

[44] www.ci.berkeley.ca.us key 'nano waste'. See also www.nytimes.com/2009/09/30/science/earth/30nano.html?_r=1,

Industry claims high-energy ionizing radiation / irradiation[45] inactivates pathogens in biosolids, and that such irradiation kills all microorganisms.

E-beam is high-energy (ten million electron volts, or 10 MeV) electron beam technology used to disinfect and stabilize biosolids. Alone, or used with chemical oxidants such as chlorine dioxide and ferrate treatments, E-beam has produced Class A biosolids. Doses between 8 and 15 kGy (kilogray) destroyed "*significant* numbers" of bacterial, viral, and protozoan pathogens, and there was no pathogen regrowth in the E-beam treated biosolids samples (our italics).[46] *Significant* numbers does not suggest the *total* number of pathogens.

A study has shown that a handful of genetic mutations give E. coli the capacity to withstand doses of radiation that would otherwise kill the microbe.[47] These findings have implications for a better understanding of how organisms can resist radiation damage to cells and repair damaged DNA. Further, not all microorganisms are destroyed at the same dose due to an ability to repair their genetic material. Therefore, a pre-requisite to ensure the right levels are used to maintain lethal effects for ionizing and non-ionizing radiations has to establish the absence of undesirable secondary effects in the irradiated material.[31]

Studies have also shown irradiation can produce mutant bacteria such as new forms of salmonella[48], E-coli and other harmful bacteria.[49] Irradiation can also bring about chemical transformations by primary and secondary radiolysis effects.[50] Mutations[51] are generally more common in lower organisms due to their shorter life spans. That is why bacteria and viruses evolve or devolve faster than human beings or animals with much longer life spans.[52]

Parasites and insect pests with large amounts of deoxyribonucleic acid (DNA) are killed by an extremely low dose of irradiation. It takes more irradiation to kill bacteria, because they have less DNA. Viruses are the smallest pathogens that have DNA and are generally resistant to irradiation at dose levels approved for foods[53] and irradiation does not destroy all bacteria in food.[54]

5. Chemicals

The dumping of sludge and transfer of contaminants to soil is of eco-toxicological relevance.[55] Evidence of contaminant accumulation in soil has occurred on land treated with

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[45] Radiation is a process where energy is released from a surface, e.g. the sun. Irradiation is the process of radiation falling on a surface. Ionizing radiation is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionized. http://www-pub.iaea.org/mtcd/publications/pdf/te_1598_web.pdf http://www-naweb.iaea.org/napc/iachem/working_materials/RC-1188-2-report.pdf

[46] http://www.werf.org/c/KnowledgeAreas/Biosolids/News/E_Beam_Irradiation_T.aspx

[47] 'Evolution of extreme resistance to ionizing radiation via genetic adaptation of DNA repair', Byrne et al, DOI: http://dx.doi.org/10.7554/eLife.01322, 4 March 2014

[48] http://www.ncbi.nlm.nih.gov/pmc/articles/PMC251611/

[49] 'Cytotoxic and mutagenic effects of irradiated substrates and food material', Kesavana and Swaminathana, Radiation Botany, Volume 11, Issue 4, 1971, Pages 253–281, DOI: 10.1016/S0033-7560(71)90017-2, http://www.sciencedirect.com/science/article/pii/S0033756071900172

[50] Irradiation / ionising radiation create chemical transformations by primary and secondary radiolysis effects. http://www.efsa.europa.eu/en/efsajournal/pub/1930.htm

[51] A change in DNA - called *mutation* - happens when the body makes copies of DNA so that the cell can divide and still keep a complete set. Irradiation and radiation can make mutations happen more often. Irradiation relies on ionizing radiation which mostly comes from radioactive sources. Several kinds of ionizing radiation will cause DNA damage. http://scienceline.ucsb.edu/getkey.php?key=1940

[52] http://agreenroad.blogspot.co.nz/2013/07/low-dose-radiation-and-antibiotics.html

[53] http://uw-food-irradiation.engr.wisc.edu/Facts.html

[54] http://uw-food-irradiation.engr.wisc.edu/Facts.html

[55] http://ec.europa.eu/environment/waste/sludge/pdf/organics_in_sludge.pdf

sewage sludge. Livestock ingesting the soils potentially cause significant transfer of contaminants from soil to edible tissues of livestock. Biosolids can also adhere to forage crops and can be ingested by grazing stock.[56]

Some contaminants degrade relatively quickly in a soil system, yet may pose a risk to groundwater. Long-chained nonylphenols, for example, have potential for leaching into ground water, may bio-accumulate, and are known to be highly toxic to living organisms. Pre-treatment must meet quality requirements, and ongoing soil observation and testing be undertaken.[57]

Applications of biosolids on agricultural land can contaminate soils with the chemicals in household and personal care products (PPCPs). When researchers studied the occurrence and dissipation of three typical azole biocides[58] in biosolids-conditioned soils and the uptake of the biocides by plants, the biocides were detected in biosolids-amended soils and undetected in control soils. High biosolid application rates and/or repeated biosolid applications, could lead to higher persistence of biocides in agricultural soils. As shown in other studies, these may potentially be taken up by plants.[59]

Water is a key factor in most plant processes. Among other uses, it serves as solvent, transport medium and reactant for uptake, translocation, and degradation of anthropogenic[60] chemicals in plant and soil. Water and solutes move freely from soils to plant roots and are transported throughout the plant by its xylem and phloem systems.[61]

It is important to realise that plants can translocate compounds to eatable parts of plants; for example, there is evidence lipid-rich roots like carrots accumulate compounds.[48]

Plant uptake of organic chemicals is associated with applying biosolids to land and the role of vegetation in cycling POPs.[62] Ironically, bio-concentration of chemicals in plants can be used for contaminated soil remediation to some extent by using the uptake capability of plants, although much of the effect is due to microbiological degradation.[48]

It is essential for regulatory authorities to keep up with the release of new chemicals used in household and personal care products and regulate appropriately.

5.1 Pesticides

A typical food chain bioaccumulation process is plant uptake from soil or spray, animal eating plant, human eating animal and/or the plant. Each step can result in increased

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56 http://ec.europa.eu/environment/waste/sludge/pdf/organics_in_sludge.pdf
57 http://ec.europa.eu/environment/waste/sludge/pdf/organics_in_sludge.pdf
58 A biocide is a chemical substance or microorganism which can deter, render harmless, or exert a controlling effect on a harmful organism by chemical or biological means. Many biocides are synthetic. Natural biocides can be derived from bacteria and plants.
59 *'Typical azole biocides in biosolid-amended soils and plants following biosolid applications'. Chen et al, J Agric Food Chem. 2013 Jul 3;61(26):6198-206. doi: 10.1021/jf4013949. Epub 2013 Jun 24. http://www.ncbi.nlm.nih.gov/pubmed/23756711; *'Uptake of pharmaceutical and personal care products by soybean plants from soils applied with biosolids and irrigated with contaminated water', Wu et al, Environ Sci Technol. 2010 Aug 15;44(16):6157-61. doi: 10.1021/es1011115, http://www.ncbi.nlm.nih.gov/pubmed/20704212; *'Fate and uptake of pharmaceuticals in soil-plant systems', Carter et al, J Agric Food Chem. 2014 Jan 29;62(4):816-25. doi: 10.1021/jf404282y. http://www.ncbi.nlm.nih.gov/pubmed/24405013
60 Chiefly of environmental pollution and pollutants originating in human activity.
61 'Uptake of Organic Pollutants in Plants', Literature survey by Anna Hellström, Swedish University of Agricultural Sciences, Uppsala, Rapport 2004:1, http://info1.ma.slu.se/IMA/Publikationer/internserie/2004-01.pdf
62 'Plant uptake of non ionic organic chemicals', Collins, Fryer and Grosso, Env Sci Tech. 2006 Jan 1;40(1):45-52. http://www.ncbi.nlm.nih.gov/pubmed/16433331

bioaccumulation including toxins where absorption of a substance is at a rate greater than that at which it is lost or eliminated from the system.[63]

A study detected glyphosate in 43.9% of urine samples taken from residents in urban areas in 18 European countries.[64] It suggests a significant portion of the human population has glyphosate in their bodies.[65] Many other pesticides are also measured in urine, especially organophosphates, synthetic pyrethroids, POPs, and pesticides such as DDT, dieldrin, etc., which are toxic at lower levels of exposure than glyphosate.

Urine, including any of these toxic contaminants, ends up in a waste treatment plant and becomes part of the biosolids process.

A one-year monitoring project of three wastewater treatment plants and one composting unit in France detected glyphosate[66] and AMPA in all samples of sludge. The highest level of glyphosate was 2.9 mg/kg and of AMPA 33.3 mg/kg, although some of the latter may be attributable to household cleaning products containing aminophosphonates (Ghanem et al 2007[67])

Another study concluded animals and humans eating transgenic soy "chronically incorporate unknown amounts of this herbicide".[40]

Residues of glyphosate in the tissues and organs of food animals fed with genetically engineered feed[68] are not regulated or tested for in New Zealand.

Glyphosate, noted as present in biosolids and human urine, would be a major source of an EDC (endocrine (hormone) disruptive chemical), being itself an EDC and combining with soy phytoestrogens.

Most pesticides are organic compounds comprised mostly of carbon, hydrogen, nitrogen, and sulphur. How long pesticides and other chemical compounds persist in soil depends on several factors including light, temperature, and soil moisture. Pesticides dissipate in several ways including photo-degradation, chemical degradation, hydrolysis, microbial degradation, leaching, and volatilization. [69] Microbial degradation occurs when soil microorganisms use chemical compounds as a food source. When the same chemical is repeatedly applied microorganisms that favour the chemical/s increase in number. These microorganisms can persist in composted material.[70]

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63 http://extoxnet.orst.edu/tibs/bioaccum.htm, http://www.saferchemicals.org/resources/chemicals/pbts.html

64 Glyphostate is the active ingredient in Round Up and a number of other herbicides, and glyphosate-resistance applies to a substantial number of herbicide-resistant genetically engineered commercial food crops.

65 http://www.foeeurope.org/sites/default/files/press_releases/foee_1_introducing_glyphosate.pdf

66 Glyphosate is the active ingredient in Roundup and a number of other propriety herbicides.

67 Ghanem A, Bados P, Estaun AR, de Alencastro LF, Taibi S, Einhorn J, Mougin C. 2007. Concentrations and specific loads of glyphosate, diuron, atrazine, nonylphenol and metabolites thereof in French urban sewage sludge. Chemosphere 69:1368-73. See also the other pesticides in this study

68 'Detection of Glyphosate Residues in Animals and Humans'. Krüger et al., J Environ Anal Toxicol 2014, 4:2 http://dx.doi.org/10.4172/2161-0525.1000210, J Environ Anal Toxicol4: 210. doi: 10.4172/2161-0525.1000210, http://omicsonline.org/open-access/detection-of-glyphosate-residues-in-animals-and-humans-2161-0525.1000210.pdf.

69 http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1030652583&topicorder=3&maxto=5 and http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1030652583&topicorder=3&maxto =5http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1057703469&topicorder=2&maxto=6

70 'Herbicide residues in field soils', James Altland, Ph.D. Oregon State University, http://oregonstate.edu/dept/nursery-weeds/feature_articles/herbicide_carryover/herbicide_carryover.htm

5.2 Pharmaceuticals

Land applications of biosolids can potentially introduce pharmaceutical and personal care products (PPCPs) into the environment.[71] Research has shown pharmaceuticals in biosolids, applied as fertilizer, can be taken up by plants grown in the treated soil.[72] This accumulation raises significant public health concerns about use of biosolids on soils used to grow food crops or raise animals for human food products.

A study has shown that plants can extensively transform contaminants after uptake through phases I and II metabolism to a large diversity of products.[73] In exploring the fate and uptake of pharmaceuticals (carbamazepine, diclofenac, fluoxetine, propranolol and sulfamethazine) and a personal care product (triclosan[74]) in soil–plant systems, the study found five of the six chemicals targeted in the study were detectable in plant tissue. All the pharmaceuticals were still detectable in the pore water at the end of the experiment. The study showed plant species have the ability to accumulate pharmaceuticals from soils. Potentially, human bioaccumulation[51] could follow ingestion of food plants containing pharmaceuticals and PPCPs from biosolids.

There is concern that the recent rise in human reproductive problems including infertility[75] may be attributable to residues of oral contraceptives in wastewater systems. Such estrogenic compounds are chemicals known as endocrine-disruptors (EDCs). Synthetic estrogen from oral contraceptives is only one source of EDCs in water. Findings cite synthetic estrogens in crop fertilizer, synthetic and natural estrogens from livestock, and industrial chemicals, like the plastic additive bisphenol-A (BPA). Chemicals in pharmaceuticals such as anti-seizure medications and anti-depressants may mimic estrogenic compounds.[76]

It has also been suggested that environmental exposure to estrogenic chemicals are a risk factor for several human health outcomes including testicular dysgenesis syndrome, hypospadias, testicular cancer, breast cancer, endometriosis, and decreased sperm counts.[77] There is evidence accruing for other disorders.
The uptake into plants and organisms of pharmaceutical and PPCP contaminants in biosolids could lead to potential bio-accumulation of chemicals in humans and animals ingesting contaminated plants.

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[71] Determination of the persistence of pharmaceuticals in biosolids using liquid-chromatography tandem mass spectrometry', Wu Chenxi et al 2008 www.sludgenews.org/resources/documents/Wu_Chenxi.pdf.

[72] 'Uptake of pharmaceuticals and personal care products by soybean plants from soils applied with biosolids and irrigated with contaminated water', Wu et al 2010, Environ Sci Tech http://dx.doi.org/10.1021/es1011115.

[73] 'Identification of Plant Metabolites of Environmental Contaminants by UPLC-QToF-MS: The in Vitro Metabolism of triclosan in Horseradish', Macherius et al, J. Agric. Food Chem., 2014, 62 (5), pp 1001–1009 DOI: 10.1021/jf404784q, www.pubfacts.com/detail/24456336/Identification-of-plant-metabolites-of-environmental-contaminants-by-UPLC-QToF-MS:-the-in-vitro-meta

[74] Triclosan, an antibacterial used in soaps, personal care products, toys, kitchenware, linked to 'superbugs', immune deficiencies, birth defects, health problems, banned in some countries from food markets, materials touching food.

[75] 'Are Oral Contraceptives a Significant Contributor to the Estrogenicity of Drinking Water?' Wise et al, 2010 http://www.coe.ucsf.edu/coe/spotlight/env_hlth+wm/contraceptives_water.pdf

[76] Association of Reproductive Health Professionals, August 2011 Birth Control Hormones In Water: Separating Myth From Fact, Moore et al http://www.arhp.org/publications-and-resources/contraception-journal/august-2011

[77] 'Inhibition of human aromatase by mammalian lignans and isoflavonoid phytoestrogens'. Adlercreutz et al, Steroid Biochem Mol Biol. 1993 Feb;44(2):147-53. http://www.ncbi.nlm.nih.gov/pubmed/8382517. 'Evaluation of an estrogen receptor-beta agonist in animal models of human disease, Harris et al, 2006, Endocrinology. 2003 Oct;144(10):4241-9 http://www.ncbi.nlm.nih.gov/pubmed/14500559. 'Testicular dysgenesis syndrome: an increasingly common developmental disorder with environmental aspects', Skakkebaek et al, Hum. Reprod. 2001, 16 (5) 972-978, http://www.ncbi.nlm.nih.gov/pubmed/11331648.

5.3 Other Persistent Organic Pollutants (POPs)

Sludge-borne persistent organic pollutants - including PBDEs, tetraBDE, PFOS, PFOA, etc - are subject to a variety of processes; e.g. adsorption / desorption, degradation (biotic and abiotic), volatilization, erosion / runoff and leaching. They can accumulate in soils.[18]

Organotins are widely used organometallic compounds with high fungicidal, bactericidal, algicidal and acaricidal properties. Of particular environmental threat is the high toxicity of tributyl-, triphenyl-, and tricyclohexxyltin derivatives. Organotins are used as agrochemicals and as general biocides.

The dumping of sludge and transfer to soil gives rise to organotin pollution of aquatic and terrestrial systems.[78]

Biosolids in New Zealand

Guidelines for New Zealand specify the pathogen and vector reduction requirements to be met with biosolids applications. Pathogens in sewage sludge are not totally killed unless temperatures of over 50°C are maintained for at least five hours. Before they can be spread on land used for agriculture, horticulture or forestry, or in home gardens, biosolids must be fully disinfected, that is free of pathogens - unless there is a six- to 12-month-long period of public and stock exclusion in place where the land to be treated is used to grow food crops or graze animals as food.

Generally, averages for nutrients, metals and organics are approximated.

As demonstrated, applications of biosolids are of concern with respect to human, animal and environmental health, because -

- Biosolids contain heavy metals and other toxic contaminants including persistent organic pollutants.[79]
- Biosolids' processing can concentrate heavy metals and other contaminants which can further accumulate in soil treated with biosolids.
  For toxicity of metals see https://www.osha.gov/SLTC/metalsheavy/.
- Biosolids may also retain mutated microorganisms as a result of irradiation processing, and contain viable transgenic DNA and residual pathogenic micro-organisms[80] which may pose risks.[81]
- Biosolids' contaminants can be taken up into plants[82] [83] which is especially risky in respect of food crops and animals raised for food or feed.

[78] http://ec.europa.eu/environment/waste/sludge/pdf/organics_in_sludge.pdf
[79] Stevens et al., 2003; Sarmen et al, 2006; Gielen et al 2009
[80] NZWWA 2003; Horsewell et al., 2007
[81] The New Zealand Forest Research Institute, trading as Scion, have produced 'Best Management Practices for Applying Biosolids to Forest Plantations in New Zealand' http://www.envirolink.govt.nz/PageFiles/520/742-TSDC53%20Best%20management%20practices%20for%20applying%20biosolids%20to%20forests.pdf
[82] Priester, JH et al, 'Soybean susceptibility to manufactured nanomaterials with evidence for food quality and soil fertility interruption', *Proceedings of the National Academy of Sciences*, 20 August 2012, tinyurl.com/pjodmol
[83] Werlin, R et al., 'Biomagnification of cadmium selenide quantum dots in a simple experimental microbial food chain', *Nature Nanotechnology*, December 2010, www.nature.com/nnano/journal/v6/n1/abs/nnano.2010.25.html

Biosolids research in New Zealand is driven by the 'Waste Strategy 2002' which specifies that over 95% of municipal biosolids and commercial organic wastes currently disposed of to landfill have to be composted, treated for methane emission, or beneficially used.
There are currently two Government funded research programmes investigating re-use options for biosolids:

- The Institute of Environmental Science and Research Limited (ESR) 'Safe and Beneficial Use of Biosolids (Sewage Sludge) on Land' http://www.esr.cri.nz/search/Results.aspx?k=biosolids

- SCION 'Waste to Resources' - 'Best Management Practices for Applying Biosolids to Forest Plantations in New Zealand' Scion (NZ Forest Research Institute) 2010 http://www.envirolink.govt.nz/PageFiles/520/742-SDC53%20Best%20manage ment%20practices %20for%20applying%20biosolids%20to%20forests.pdf

Both projects involve collaborations with national and international research providers including the Universities of Lincoln, Canterbury, Waikato and Massey, Local and Regional Councils, and community groups, together with -

Landcare Research - 'The Cost-Benefits of Applying Biosolid Composts for Vegetable, Fruit and Maize/Sweetcorn Production System sin New Zealand'
http://www.landcareresearch.co.nz/publications/researchpubs/LRSciSeries27_Cameron2004_4web.pdf

National Institute of Water and Atmospheric Research (NIWA) - 'Guidelines for the safe application of biosolids to land in New Zealand' –
https://library.niwa.co.nz/cgi-bin/koha/opac-detail.pl?biblionumber=170118

HortResearch - 'Organic residues in sewage biosolids: summary of the New Zealand CDRP Project results' - http://www.esr.cri.nz/competencies/water/Pages/OrganicResiduesinBiosolids.aspx

AgResearch – no information immediately available

National Biosolids Research Programme (Australia) -
http://www.csiro.au/Outcomes/Environment/Australian-Landscapes/National-Biosolids-Research-Program.aspx

Sewage Sludge and Soil Fertility (UK) - 'Effects of sewage sludge on agricultural productivity and soil fertility (Phase III) - SP0130'
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=10677

Research results are disseminated through end-user meetings and The New Zealand Land Treatment Collective (LTC) - http://www.scionresearch.com/general/new-zealand-land-treatment-collective.
The LTC membership represents governmental agencies at all levels (local, regional, national), and private industry. The organisation was established to support the extension of research into the treatment of wastes and waste products by land application, providing its members with the most recent information on land treatment technology, research and information.

Conclusions

The main goal for safe use of biosolids produced from sewage sludge must be to establish the best waste management solutions that improve sustainability by safely transforming sewage waste into potentially renewable resources in ways that do not add to further contamination of the environment and our food chain.

Establishing these solutions requires:

- Establishing the full risks associated with the processes involved and maintaining frequent monitoring and testing;
- Determining the environmental fate and effects of contaminants from biosolids applied to land or used in other ways;
- Establishing culturally and socially acceptable ways of utilising biosolids that do not add to further contamination of the environment and the food chain.[84]

Precautionary principle

Biosolids containing contaminants applied to land growing food crops or applied to pasture raising livestock for food have been shown to end up in the food chain. The contaminants come full circle when humans eat the crops grown on the land, and/or consume the meat or drink the milk of animals that directly or indirectly ingest biosolids. This is an area that needs extensive, in-depth research by independent scientists. Governments and regulatory authorities must adopt the precautionary principle in order not to perpetuate the addition of contaminants to the food chain.

The information on chemical contaminants in biosolids was reviewed by Kirstie Murdoch of the National Toxics Network. http://www.ntn.org.au/contributor-posts/dr-kirstie-murdoch

[84] http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID =10677

See also

- **Sustainable Wastewater Management** www.esr.cri.nz/competencies/water/Pages/wastewatermanagement.aspx
- **Australia and New Zealand Biosolids Guidelines** http://www.biosolids.com.au/aust-nz-guidelines.php
- **Water New Zealand - Guidelines – biosolids** http://www.nzwwa.org.nz/Category?Action=View&Category_id=106
- **New Zealand Overview** http://www.iwawaterwiki.org/xwiki/bin/view/Articles/New+Zealand
- **Users' Guide National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health**, April 2012 http://www.mfe.govt.nz/publications/rma/users-guide-nes-for-assessing-managing-contaminants-in-soil/guide-nes-for-assessing-managing-contaminants-in-soil.pdf
- **Waste publications** https://www.mfe.govt.nz/publications/waste/
- **Waste - Best practice guides and guidelines** www.mfe.govt.nz/publications/waste/#guides
- **'Land application of sewage sludge (biosolids) in Australia: risks to the environment and food crops'** Pritchard et al, Water Sci Technol. 2010;62(1):48-57. doi: 10.2166/wst.2010.274. http://www.ncbi.nlm.nih.gov/pubmed/20595753
- **Sewage Sludge Action Network** http://sewagesludgeactionnetwork.com/content/sewage-sludge-or-biosolids-is-it-toxic-hazardous-solid-waste-or-safe-fertilizer-ignorance-confusion-and-lies
- **'Organic contaminants in sewage sludge for agricultural use'**, European Commission http://ec.europa.eu/environment/waste/sludge/pdf/organics_in_sludge.pdf
- **Best Managements Practices for Applying Biosolids to Forests in New Zealand**, Scion http://www.envirolink.govt.nz/PageFiles/520/742-TSDC53%20Best%20management%20practices%20for%20applying%20biosolids%20to%20forests.pdf
- **Cost-Benefits of Applying Biosolid Composts For Vegetable, Fruit, and Maize/Sweetcorn Production Systems in New Zealand**, Landcare Research Science Series No. 2 2004 www.landcareresearch.co.nz/publications/researchpubs/LRSciSeries27_Cameron2004_4web.pdf
- **Comparison of soil guideline values used in NZ and their derivations**, Landcare Research http://ecan.govt.nz/publications/Reports/ComparisonofSoilGuidelineValuesinNewZealand.pdf
- **National Toxics Network Australia** http://www.ntn.org.au/
- **Various** http://natlib.govt.nz/items?i[is_catalog_record]=false&i[subject]=Chemicals