Physicians and Scientists for Global Responsibility

New Zealand Charitable Trust

Nanotechnology

from a New Zealand perspective

Nanotechnology refers to techniques used intentionally to engineer structures, materials and systems that operate at a scale of 100 nanometres (nm) or less. This is the manipulation of matter at the scale of atoms and molecules.

Nano is not an object – it is a measurement. Unlike *bio*technology, where the *bios* (life) is being manipulated, nanotechnology speaks solely to scale. One nanometre (nm) is one billionth of a metre.

A line of 10 atoms of hydrogen would approximate one nanometre. The diameter of a strand of DNA is about 2.5 nm, a virus approximately 100 nm and a red blood cell 2000 to 5000 nm. A human hair will measure between 80,000 and 100,000 nm in width; and something we may handle daily, an 80 gm sheet of A4 paper, is of similar thickness, about 100,000 nm (a tenth of a millimetre). A grain of sand is "huge" at one million nanometres (one millimetre).

Nanotechnology as it is today began when we gained the tools to extend imaging and measuring into the nano-scale. Only the strongest microscopes allow us to image anything at that scale: nano-particles, nano-structures and nano-materials.

Researchers seeking to understand the fundamentals of properties at the nano-scale call their work nano-science. Those investigating the effective use of the properties call it nano-engineering. In fact, many fields contribute to nanotechnology, including molecular physics, materials science, chemistry, biology, computer science, electrical engineering, and mechanical engineering. Because of the range and generality of the definition, some scientists use the term *nanotechnologies* rather than *nanotechnology*.

When we breathe city air, we inhale nano-particles, incidental by-products of intentionally engineered products. These could include vehicle exhaust and industry emissions. When a volcano erupts it creates nano-particles which we may end up inhaling. Many of these nano-particles are potentially toxic and many factors can play a part in that toxicity, for example, variations in exposure levels and individual physiological responses.

Manufactured nano-materials may offer promising benefits and potential risks. The distinctive features that make them useful may also play a part in their potential toxicity. At the nano-scale, properties such as melting point, fluorescence, electrical conductivity, magnetic permeability, and chemical reactivity change as a function of size. The exposed surface area of a material increases rapidly as it is subdivided into smaller and smaller particles, often leading to the emergence of new properties when nano-scale particle size is reached. Such properties may depend on quantum effects – physical phenomena related to the dual wave-particle nature of matter that we do not usually encounter in any direct way in our everyday lives. Here are some examples:

- Carbon graphite – as in the pencil lead we use – is normally soft and malleable. At the nano-scale, it can become stronger than steel, although it is six times lighter.
- Aluminium – as used to manufacture beer and soft drink cans – can spontaneously combust at the nano-scale.
- In bulk, gold is inert; at the nano-scale it can bind to human DNA.
- Zinc oxide - usually white and opaque – becomes transparent at the nano-scale, hence its popularity for use in sunscreens.

There is a regulatory gap for nanotechnology which is reflected in US practice. When a chemical substance is commercialised in the US it is included in the federal Toxic Substances Control Act Chemical Substance Inventory and the Environmental Protection Agency (EPA) considers that it "exists". The same chemical at the nano-scale requires no further testing. As shown above, nano-scale materials take on different characteristics and their new qualities may be toxic. The precautionary principle should apply. At every application of nanotechnology, regulations should require a strict process of research, safety testing and analysis. Many regulatory authorities around the world apply the same findings as US regulatory bodies with little or no further caution.

A brief history of nanotechnology oversight in New Zealand

2006 – The Ministry of Research, Science and Technology (MoRST) released a commissioned report, 'Nano-science and nanotechnology research case study: the practical benefits resulting from collaboration between social scientists and nanotechnology researchers' compiled by corporate authors, Taylor Baines and Associates.[1] It described the findings of three case studies that looked at collaboration between social scientists and nanotechnology researchers. The report highlighted some of the advantages of this type of collaboration, and aimed to help the New Zealand government design a roadmap for encouraging future collaborations in the field of nanotechnology.

2007 - The New Zealand government released its 'Nano-science and Nanotechnologies Roadmap'. It gave strategic priority to nanotechnology-related research and policy saying New Zealand needed to take a considered approach to nano-science and nanotechnologies (both at a research and policy level) so that maximum benefit can be derived from investments and the country well placed to appropriately adapt or adopt nanotechnologies developed elsewhere.[2]

2008 - 'Tikanga and Technology – a new net goes fishing' was a hui that involved the Environmental Risk Management Authority (ERMA New Zealand; now the responsibility of the New Zealand Environmental Protection Authority [EPA]), the Allan Wilson Centre for Molecular Ecology and Evolution (AWC) and the Institute of Geological and Nuclear Sciences (GNS Science). The hui sought to explore the potential impacts, risks, benefits, and applications of new and emerging genetic and nanotechnologies. It looked at the research in New Zealand using these technologies, involved some of the researchers, and had an overarching goal to consider any implications for tikanga and mātauranga Māori (customary practice and knowledge), particularly with regard to the role of kaitiakitanga (guardianship) over native species, the environment and human health.[3]

2009 - MoRST issued the report, 'Nanotechnology Here and Now, Proceedings from the Conversations of the Workshop 23-24 April 2009'. It summarized the results of a workshop focused on the steps the New Zealand government needed to take to ensure it has a regulatory system in place that is able to deal with the challenges and opportunities associated with nanotechnologies. It outlined over seventy different steps the government should take, including agreeing on a definition for nanotechnology, developing a labelling system for nano-enabled products, and maintaining a public database of these

1 www.msi.govt.nz/assets/MSI/MoRST-Archive/Nanotechnology-and-Social-Science-Case-Study-summary.pdf ISBN: 0-478-06141-2
2 http://www.msi.govt.nz/update-me/archive/publications-archive/#n
3 See http://www.epa.govt.nz/Publications/Tikanga-and-Technology-I-2008-2009-report.pdf.

products. It states there were limited commercial nanotechnology developers in New Zealand at that time, although there was extensive research, and that New Zealand imported nano-products, nano-processes and nano-services. The workshop was attended by academics, government officials, representatives from NGOs and social and environmental scientists.[4]

2010 - MoRST commissioned a review of the suitability of New Zealand's regulations appropriately to manage manufactured nano-materials. It was carried out in consultation with other government agencies, and followed the 2009 workshop on nanotechnology and similar reviews overseas. The review claimed it did not represent government policy.[5]

2010 – In July, PSGR requested up to the minute information from MoRST on what was being done to oversee nanotechnology in New Zealand. Dr Robert Hickson, then Acting Director, Emerging Technologies, responded on behalf of MoRST:

"We are currently reviewing the regulations that are relevant to nano-materials in New Zealand. This includes looking at the Hazardous Substances and New Organisms Act, the Health & Safety in Employment Act, the Waste Minimisation Act, and a range of other pieces of legislation. The purpose of the review is to identify any significant gaps associated with the regulation of manufactured nano-materials (we are using the term "manufactured nano-materials" to make a distinction from naturally occurring nano-particles). We expect the report on this review to be made publicly available in August, and this may help further address your enquiry.

"Research continues internationally to identify hazards and potential risks associated with a range of different types of manufactured nano-materials, and effective methods for eliminating or managing these risks, and there is a growing interest in life cycle analysis of manufactured nano-materials. While risks associated with some specific nano-materials have been identified, for many nano-materials there still remains no or limited knowledge. Funding to investigate potential risks of nano-materials is increasing, but given the variety of nano-materials knowledge gaps for many types of manufactured nano-materials will remain.

"New Zealand is involved in international fora, such as the OECD, to help identify priorities for research and to develop standards for testing manufactured nano-materials. Research organisations are investigating potential risks of some manufactured materials, and reviewing health and safety procedures associated with producing, handling and disposing of nano-materials in laboratories.

"MoRST's position is that we need to remain aware and vigilant of developments in risk and regulatory issues associated with manufactured nano-materials, and we are undertaking this by sharing information on nanotechnology developments with regulatory agencies. MoRST also sees a need to support capabilities here to detect, assess and manage manufactured nano-materials. A range of research groups are investigating potential risks associated with nano-materials."[6]

2011 – 'A Review of the Adequacy of New Zealand's Regulatory Systems to Manage the Possible Impacts of Manufactured Nano-materials Final Report' by Colin Gavaghan and Jennifer Moore was published.[7]

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4 See http://ethics.iit.edu/NanoEthicsBank/node/513; 'Setting directions for nanotechnology in New Zealand', Robert Hickson PhD, International Journal of Nanotechnology, Volume 6, Number 3-4 / 2009, pp 288 – 297, www.inderscience.com/search/index.php?ction=record&rec_id=22920&prevQuery=&ps=10&m=or. "Biotechnology and Nanotechnology in the Future", compiled by Dr Robert Hickson when Senior Adviser (Bio–issues Forums) for MoRST is no longer available on the Internet.

5 'A Review of the Adequacy of New Zealand's Regulatory Systems to Manage the Possible Impacts of Manufactured Nano-materials, Final Report' 2011 Gavaghan and Moore www.msi.govt.nz/assets/Archive/Nanotechnology-review.pdf.

6 N.B. Following the departure of Dr Hickson from MoRST, subsequent emails from PSGR to MoRST and now the Ministry of Science and Innovation (MSI) remain unanswered.

7 http://www.msi.govt.nz/assets/Archive/Nanotechnology-review.pdf.

2013 - Substances created using nanotechnology come under the Hazardous Substances and New Organisms Act 1996 (HSNO Act) [8] and are overseen by the EPA if they have hazardous properties:

"The HSNO Act does not regulate technologies, or the application of new technologies. Instead, the Act regulates substances that have specific hazardous properties: explosiveness, toxicity, capacity to oxidise, ecotoxicity, flammability or corrosiveness. A substance created using nanotechnology would only be regulated under the HSNO Act if it had one or more of these hazardous properties.[9] The EPA has specific requirements for importing or manufacturing cosmetic products containing nano-particles (other than zinc oxide or titanium dioxide) in New Zealand."[10] [11]

On 26 February 2013, the Ombudsman upheld the public's right to know about the use of nano-particles in cosmetic products and in a first step to regulating nano-materials, the EPA has made it compulsory to label for nano-scale ingredients in cosmetics, but not until 1 July 2015. It seems that the HSNO Act as detailed above has to suffice for regulating nano-materials and nanotechnology in general in New Zealand for the immediate future.

Find out more from the Ministry of Business, Innovation and Employment http://www.msi.govt.nz/ and the Environmental Protection Authority http://www.epa.govt.nz/; keyword 'nanotechnology'.

Recommended:

'Social and Environmental Implications of Nanotechnology Development in the Asia-Pacific Region', Senjen, Foladori & Azoulay (2013).[12] http://www.ipen.org/sites/default/files/documents/Social%20and%20Enviro%20Implications%20of%20Nano%20Development%20in%20Asia-Pacific.pdf

'Nanomedicine - new solutions or new problems?' Rye Senjen (pub. December 2013).[13] http://noharm-europe.org/sites/default/files/documents-files/2462/HCWH%20Europe%20Nanoreport.pdf

See also Addendum One.

Nanotechnology patents and potential market value of nanotechnology

A Reuters report claimed "US-based inventors accounted for 54 percent of the nanotechnology patent applications and grants" as reviewed in a study by law firm McDermott Will & Emery, "followed by South Korea with 7.8 percent, Japan 7.1 percent, Germany 6.2 percent and China 4.9 percent." The study examined published US patent applications, patents granted by the US Patent and Trade Office, and published international patent applications that had the term 'nano' in the claims, title, or abstract.[14]

Patent offices worldwide recently began classifying nanotechnology under the International Patent Classification (IPC) system, using a uniform symbol, B82Y.[15] Nanotechnology has generated substantial economic activity and will play a role in many industries. A wide range of products based on or involving nanotechnology are already marketed and the potential future returns on these have been quoted in the trillions of dollars.

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8 Ministry for the Environment, https://www.mfe.govt.nz/issues/managing-environmental-risks/hazardous/about/nanotechnology.html.
9 Products of technology, NZ Ministry for the Environment www.mfe.govt.nz/issues/managing-environmental-risks/hazardous/about/nanotechnology.html.
10 Cosmetic products group standard's requirements www.epa.govt.nz/hazardous-substances/approvals/group-standards/Pages/cosmetic.aspx.
11 https://www.mfe.govt.nz/issues/managing-environmental-risks/hazardous/laws/regulations.html.
12 NTN (National Toxics Network Australia)/ ReLANS (Latin American Nanotechnology and Society Network) / IPEN (International POPs Elimination Network).
13 Health Care Without Harm Europe.
14 www.reuters.com/article/2013/02/14/us-patents-nanotechnology-idUSBRE91D0YL20130214 14 February 2013
15 http://www.epo.org/news-issues/issues/classification/nanotechnology.html

A more realistic forecast is given in 'Nanotechnology: A Realistic Market Assessment' from market analyst firm BCC Research. In 2010, the products of nanotechnology had an estimated value worldwide of over US$800 million. By 2016, the market is predicted to reach US$2.4 billion, "a five-year Compound Annual Growth Rate (CAGR) of 19.2% in unit terms and 20.9% in value terms".[16]

Products of nanotechnology marketed in New Zealand and Australia

Manufactured nano-materials products known to be in use in Australasia are the composite material used for white dental fillings, cleaning materials, protective and non-stick applications on glass, personal care products, and veterinarian and pharmaceutical products. You can find a 'List of nano-materials notified to the EPA' in New Zealand on the EPA website.[17]

Here are some examples of nano-products marketed in New Zealand:

- Nanokote "protective treatment for glass" is "around 80,000 times thinner than a human hair".[18]
- Micronisers Pty Ltd specialise in nano-sized products used in "plastics, personal care, textile, coatings, veterinarian and pharmaceutical" products.[19]
- The Whitewash Sponge cleans brilliantly, but disintegrates in use. It is "made from fibres 10,000 times finer than a human hair" and available in hardware stores and supermarkets.[20]
- Sunscreens may contain nano-particles of zinc oxide and titanium dioxide. At the nano-scale, zinc oxide becomes transparent. A Therapeutic Goods Administration (TGA) review concluded its use was safe and requires no specific warnings about nano-particles on labels.[21]

What products with a 'nano' content are imported without identifying labelling are unknown.

Nano-particles and human health

A recent court case in the US found the use of nano-silver was 'ubiquitous' and could not be avoided by consumers. According to the US Woodrow Wilson International Centre for Scholars, foods containing nano-materials are entering the market at around three to four per week. The Centre's inventory of nano products[22] shows that silver is the most common nano-material mentioned in product descriptions.

In a report[23] released in May 2014, Friends of the Earth claim that food and food contact products identified as containing nano-silver include baby bottles, food containers, packaging, cutting boards, salad bowls, appliances, cutlery, ice trays, filtration devices and collapsible coolers. In agriculture nanotechnology and manufactured nano-materials involving silver are used in poultry production and agriculture, and in aquacultural disinfectants.

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[16] See graph on 'Nanotechnology: A Realistic Market Assessment' from market analyst firm BCC Research. http://www.bccresearch.com/report/nanocomposites-global-markets-nan021e.html

17 www.epa.govt.nz/ hazardous-substances/approvals/group-standards/Pages/List-of-nanomaterials-notified-to-the-EPA.aspx.

18 http://nanokote.co.nz/cms/

19 www.micronisers.com/about.htm

20 www.mitre10mega.co.nz/shop/laundry_cleaning/brushware_cloths/whitewash_sponge_325335/

21 www.tga.gov.au/pdf/submissions/review-tga-transparency-1101-submission-foe.pdf .

[22] http://www.nanotechproject.org/cpi/

[23] 'Tiny Ingredients Big Risks, Nanomaterials rapidly entering food and farming' http://libcloud.s3.amazonaws.com/93/1d/9/4694/1/TinyIngredients_BigRisks.pdf

We know that small particulate matter that includes nano-size particles can have adverse health effects; for example, those created by forest fires, industrial emissions, dust storms and/or vehicle exhaust. A study found an increase in acute bronchitis in people living in the ash stream created by the 1996 eruption of Ruapehu, New Zealand.[24] In the UK, an estimated 12,000 Londoners died as a direct result, at the time or later, of a dirt-particle-filled fog, known as smog, which enveloped the capital from 5 to 9 December1952.[25]

Society has seen adverse health effects in exposure to coal dust (pneumoconiosis) and asbestos. Asbestos fibres can enter the lungs and cause asbestosis, lung cancer and mesothelioma. In Britain, an estimated 4000 people still die annually from asbestos-related diseases and that this will continue into the 2050s. (N.B. The importation of raw amphibole [blue and brown] asbestos into New Zealand was banned in 1984 and chrysotile [white] asbestos in 2002.)[26] After the collapse of the World Trade Centre twin towers in New York in 2001, nano-particles of dust were created at ground level. Analyses of deposits several centimetres thick, found carcinogenic materials. People living in the area, or working on the rescue, became sick or disabled with respiratory illnesses.[27]

Concerns about adverse health effects also lie with emerging nanotechnologies, with intentionally manufacture nano-particles and nano-materials, their safety, advisability and regulation. Most biological and medical literature on nano-particles focuses on the application of the technology. Little research has been carried out on the toxicity of different types of manufactured nano-materials, especially their long-term risks. We know nano-particles can pass through epithelial surfaces, i.e. skin, gastrointestinal, conjunctiva, and the endothelial barriers lining blood vessels. They can be inhaled and they can pass through the blood-brain barrier. What has emerged is that there are effects at cellular level that could potentially affect humans and these effects could depend on the nano-particle base material, its size and structure, and constituents and coatings.

A study published in the European Respiratory Journal (ERJ) followed reports coming from China in 2009. Seven women, exposed to nano-particles in an inadequately-ventilated workplace, became seriously ill. Two subsequently died.

The presence of polyacrylate nano-particles was confirmed in the workplace. Pathological examinations of the patients' lung tissue displayed nonspecific pulmonary inflammation, pulmonary fibrosis and foreign-body granulomas of pleura. Using transmission electron microscopy, nano-particles were observed lodged in the cytoplasm and caryoplasm of pulmonary epithelial and mesothelial cells, and in chest fluid. These cases arouse concern that long-term exposure to some nano-particles without protective measures may be related to serious damage to human lungs.[28]

Could exposure over lengthy periods to, say, a product that disintegrates on use and potentially releases nano-particles, adversely affect the user? Could staff at a rubbish dump be affected by the projected increase in discarded nano-products entering the waste system? Such exposure is currently uncontained and uncontrolled, with nano-product waste potentially disturbed by heavy machinery ploughing deposits into the ground. Any released nano-particles could potentially be dispersed by wind and rain, and human and vehicular traffic.

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[24] 'Acute health effects of the Mount Ruapehu (New Zealand) volcanic eruption of June 1996', Hickling et al, J. Environmental Health Research, Vol 9, Issue 2, June 1999, pp 97–107 http://www.ingentaconnect.com/content/tandf/cije/1999/00000009/00000002/art00002

[25] 'The Great Smog of 1952', Jennifer Rosenberg http://history1900s.about.com/od/1950s/qt/greatsmog.htm; The Great Smog of 1952 and other cases http://en.wikipedia.org/wiki/Air_pollution

[26] Asbestos: Frequently Asked Questions http://www.inspiringpeople.co.nz/page/pageid/2145875708.html. NZ Health and Safety in Employment (Asbestos) Regulations 1998 http://www.legislation.govt.nz/regulation/public/1998/0443/latest/DLM269298.html. Standards http://shop.standards.co.nz/search/ed?q=asbestos.

[27] 'Characterization of the Dust/Smoke Aerosol that Settled East of the World Trade Centre (WTC) in Lower Manhattan after the Collapse of the WTC 11 September 2001', Environmental Health Perspectives (EHP), 7/2002; http://nymag.com/nymetro/news/politics/columns/citypolitic/n_9384/; http://en.wikipedia.org/wiki/Health_effects_arising_from_the_September_11_attacks.)

[28] 'Exposure to nano-particles is related to pleural effusion, pulmonary fibrosis and granuloma', Y Song, X Li and X Du Eur Respir J 2009, 34:559-567 doi: 10.1183/09031936.00178308. http://erj.ersjournals.com/content/34/3/559.full

Nano-particles and the health of the environment

In a 43-page Report released in May 2014, Friends of the Earth state nanotechnology offers the means of "Reformulation of on-farm inputs to produce more potent fertilizers, plant growth treatments and pesticides that respond to specific conditions or targets."

Nano-agrochemicals are being used in farming and so entering the environment, and nanotechnology poses broader challenges to the development of more sustainable food and farming systems:

"Conventional agrochemicals have polluted soils and waterways and have caused substantial disruption to ecosystems. Exposure to agrochemicals has also been linked with greater incidence of cancer and serious reproductive problems among agricultural workers and their families. Consequently, it is of great concern that nano-agrochemicals are now being used on farms and released into the environment, absent regulations that require product manufacturers to demonstrate the safety of new, more potent nano-scale formulations of existing chemicals."[23] FoE also state nanotechnology offers the means of "Reformulation of on-farm inputs to produce more potent fertilizers, plant growth treatments and pesticides that respond to specific conditions or targets."

Recent evidence from hydroponic plant studies suggests manufactured nano-materials are taken up and processed by plants. This varies with the plant and the type of nano-material. It was previously thought soils limited bioavailability of nano-materials to merely microbes and plants. Scientists now find evidence they are bioavailable in soil. 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. Nano-materials could alter the quality and yield of soil-based food crops.

In a recent scientific study, soybeans were grown to maturity in soil contaminated by nano-materials. Previous research had investigated the effects of nano-materials on hydroponic plants, planktonic bacteria, and the soil microbial community.[29] In this new study, two metal oxide nano-materials - cesium oxide (CeO_2)[30] and zinc oxide (ZnO)[31] - were added to the farm soil in which the soybean plants were grown. The results showed that for nano-CeO_2, plant growth and yield diminished, and nitrogen fixation was reduced when the concentration of nano-CeO_2 was high. For nano-ZnO the component metal was taken up and distributed throughout edible plant tissues.

The scientists referred to previously published hydroponic plant, planktonic bacterial, and soil microbial community research, to establish if manufactured nano-materials can enter the soil and build up in that environment. No study had previously grown plants to maturity in soil contaminated by manufactured nano-materials, so this study focussed on mature soybean plants.[32]

The researchers concluded that dispersing wastewater biosolids that may contain nano-materials onto food crops could lead to agriculturally associated human and environmental risks from nano-materials.

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[29] 'Soybean susceptibility to manufactured nano-materials with evidence for food quality and soil fertility interruption', Priestera et al 2012 www.pnas.org/content/early/2012/08/14/1205431109?utm_source=HEADS-UP+24-30+AUGUST++2012&utm_campaign=SMC+Heads-Up&utm_medium=email

[30] CeO2: Cerium (IV) oxide, also known as ceric oxide, ceria, cerium oxide or cerium dioxide; an oxide of the rare earth metal cerium

[31] ZnO: Zinc oxide. ZnO is known to be used in sunscreens.

[32] Globally, the soybean is a major commodity crop; in 2011 comprising 56% of oilseed production worldwide and transgenic soy representing 77% of that production. Statistics on soybean www.soystats.com/2012/Default-frames.htm; www.gmo-compass.org/eng/agri_biotechnology/gmo_planting/257.global_gm_plant ing_2009.html

In another study[33], researchers found manufactured nano-materials formed from cadmium selenide entered and accumulated in the bacterium *Pseudomonas*. They further found that the concentration of cadmium increased in a transfer from bacteria to protozoa. The manufactured nano-materials were substantially intact in the increased concentration and there was little degradation. 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 threat to diverse forms of life. A conclusion was drawn that dispersing wastewater biosolids - which may contain manufactured nano-materials – onto land could lead to agriculturally associated human and environmental risks from manufactured nano-materials.[34]

Handling nano-waste

From the above, we can see that nano-particles can be taken up by plants, but we do not fully understand what happens to manufactured nano-materials in the reduction and treatment of agricultural and industrial wastes and groundwater remediation. Nano-particles may be released when in contact with air, soil, water or chemicals, or when subjected to forces such as natural ground movement.

Biosolids from waste treatment plants are routinely dispersed onto New Zealand paddocks. Treated sewage is dispersed into water systems and the sea. Biosolids and liquid sewage will increasingly contain manufactured nano-materials.[35] We currently have no way of tracking nano-particles in the environment, or a guaranteed way of removing them from soil or water or the human body. Manufactured nano-materials may be absorbed by soil, reduce bioavailability, or harm soil bacteria (the engine of the ecosystem) and organisms higher in the food chain. Manufactured nano-materials may be able to break down, but we do not know how long it will take. When thinking about how to manage nano-material waste, it is essential to examine the entire life cycle of nano-materials from synthesis to disposal.[36]

Nano-waste must be identified and disposed of safely. This includes, for example, nano-materials, items contaminated with and liquids containing nano-materials, and nano-materials released under normal environmental conditions or movement. Manufactured nano-materials in the environment may come from many sources, such as nano-materials moulded into solids that would not normally be expected to rid themselves of nano-particles when handled or cut. Aggregated nano-materials may not be mobile, nor have the same reactivity. Some nano-materials are considered safe based on their use, for instance in medical applications, but what about their waste; for example, product and wrapping wastage as well as nano-particles finding their way into grey water?

The City of Berkeley in California was the first federal body worldwide to address nano-waste. Their guidelines require that all facilities manufacturing or using manufactured nano-particles should submit a disclosure of the current toxicology of the materials reported, to the extent known, and how the facility will safely handle, monitor, contain, dispose, track inventory, prevent releases and mitigate such materials. A Risk Management Plan may also be required.[37]

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[33] 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

[34] 'UCSB Scientists Demonstrate Biomagnification of Nano-materials in Food Chain' http://ucsb.imodules.com/s/1016/indexNL.aspx?sid=1016&gid=1&pgid=252&cid=1417&ecid=1417&ciid=1790&crid=0

[35] Mangere www.bvsde.paho.org/bvsaar/cdlodos/pdf/beneficialuse941.pdf; Guidelines for the Safe Application of Biosolids to Land in NZ, August 2003 www.waternz.org.nz/documents/publications/books_guides/biosolids_guidelines.pdf; The Cost-Benefits of Applying Biosolid Composts for Vegetable, Fruit and Maize/Sweetcorn Production Systems in NZ 2004 www.mwpress.co.nz/store/downloads/LRSciSeries27_Cameron2004_4web.pdf ; Christchurch http://researcharchive.lincoln.ac.nz/dspace/bitstream/10182/1747/1/ssd_sewage_sludge.pdf.

[36] 'Guidance for the Safe Recovery and Disposal of Wastes Containing Nano-materials' 2009, corporate authors German Chemical Industry Association http://ethics.iit.edu/NanoEthicsBank/node/2563

[37] http://www.ci.berkeley.ca.us/citycouncil/2006citycouncil/packet/120506/2006-12-05%20Item%2013%20Manufactured%20Nanoparticle%20Health%20and%20Safety%20Disclosure.pdf

In the US, the EPA is responsible for regulation regarding waste. You can monitor their site on http://nlquery.epa.gov/; submit '*nano-waste*' as your search title. The conclusion of a US Army study that looked at fullerenes[38] manufactured using nanotechnology emphasized the need for a global review of nano-manufacturing wastes and low-purity products.[39] See also 'Managing nano-particle waste in sewage'[40] and 'Health Council of the Netherlands, Nano-materials in waste'[41].

Currently, there are insufficient published government, national or local waste management "best practices" for nano-waste materials. Safety and waste management are priorities, but regulations need to control the entire life cycle of nano-materials from synthesis to disposal.

Military applications of nano-materials

One concerning focus of nanotechnology research and development is military applications: e.g. advantage that may be derived from research into nano-enhanced drug delivery systems. The US Department of Defense (DoD) has allocated significant funding towards research in nano-electronics, and nano-materials for detection and protection against biological, chemical, explosive and radiological threats. Nano-sensors and nano-coatings could help defend from chemical and biological attacks. It has been suggested soldiers could be performance enhanced using nano-nutrients and/or nano-ceuticals. It is possible delivery systems for drugs, vaccines and bioweapons could be administered without immediate detection. Chemical and biological weapons could become more sophisticated, invasive, and potentially impossible to combat.

At the Institute for Soldier Nanotechnologies at the Institute of Technology, Cambridge, Massachusetts, researchers are looking for diverse, nano-enabled functionalities to materials that can serve as building blocks for clothing and other gear that advance personnel protection and survivability capabilities.[42] Such developments could give advantages in war to those nations that are more scientifically advanced and economically wealthy, and extend to criminal or terrorist use.

Like any new technology, nano-technology offers new opportunities for the construction and modification of weaponry. International vigilance is needed to ensure that the new properties of materials offered by nano-technology are not exploited in ways that evade provisions of international agreements like the Chemical Weapons Convention.[43]

International co-operation on developments

Some co-operation does exist between multinational organizations such as the Organisation for Economic Co-operation and Development (OECD), American Society for Testing and Materials (ASTM International) and the International Organization for Standardization (ISO).[44]

Dr Robert Hickson, when representing MoRST, said:

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[38] Fullerenes are a form of carbon molecule consisting of spherical, ellipsoid, or cylindrical arrangements of dozens of carbon atoms. Fullerene molecules comprise 60 or more carbon atoms. They occur only in small amounts naturally.

[39] US Army Engineer Research and Development Centre, Hull MS et al, Environ Sci. Technol., 2009, 43 (11), pp 4169–4174 DOI: 10.1021/es802483p, http://pubs.acs.org/doi/abs/10.1021/es802483p; 'Release of metal impurities from carbon nano-materials influences aquatic toxicity', Hull M S et al, Environ Sci. Technol., 2009, 43:11 http://www.researchgate.net/publication/26333188_Release_of_metal_impurities_from_carbon_nanomaterials_influences_aquatic_toxicity

[40] http://www.isis.stfc.ac.uk/science/natural-world/managing-nanoparticle-waste-in-sewage9094.html,

[41] http://www.gezondheidsraad.nl/sites/default/files/Nano_waste_201114E.pdf

42 US Institute for Soldier Nanotechnologies at the Institute of Technology http://web.mit.edu/isn/.

[43] 'Nanotechnology and the International Law of Weaponry: Towards International Regulation of Nano-Weaponry: Towards International Regulation of Nano-Weapons' Nasu, Hitoshi; Faunce, Thomas, 2010, JILawInfoSci 3; (2009-2010) 20(1) Journal of Law, Information and Science 23, http://www.austlii.edu.au/au/journals/JILawInfoSci/2010/3.html

[44] http://www.oecd.org/; http://www.astm.org/; http://www.iso.org/

"New Zealand is involved in international fora, such as the OECD, to help identify priorities for research and to develop standards for testing manufactured nano-materials. Research organisations are investigating potential risks of some manufactured materials, and reviewing health and safety procedures associated with producing, handling and disposing of nano-materials in laboratories."[45]

Monitor developments in New Zealand on the following websites (keyword 'nanotechnology').

- New Zealand Ministry of Business, Innovation and Employment – Science and Innovation www.msi.govt.nz/home/SearchForm?Search=nanotechnology&action_results=&AudienceID=
- New Zealand Authority http://www.epa.govt.nz/
- Food Standards Australia New Zealand http://www.foodstandards.govt.nz/
  New Zealand Food Safety Authority http://www.foodsafety.govt.nz/

- US Centres for Disease Control and Prevention, http://www.cdc.gov/niosh/
- US Department of Labour, http://search.usa.gov/search?affiliate=usdolosha publicwebsite&query= nanotechnology&x=0&y=0
- US Environmental Protection Agency http://nlquery.epa.gov/, put 'nanotechnology' in search.
- US Food and Drug Administration http://www.fda.gov/
- US Department of Agriculture National Institute of Food and Agriculture http://www.nifa.usda.gov/nanotechnology.cfm
- US National Nanotechnology Initiative http://www.nano.gov/you
  Nano in the News http://www.nano.gov/newsroom/nano-news

- UK Food Standards Agency http://www.food.gov.uk/
- UK MHRA, regulating medicines and medical devices http://www.mhra.gov.uk/

Where to from here

Emerging technologies – such as genetic engineering, synthetic biology, geo- and bio-geo-engineering, and nanotechnology – present risks we do not yet fully understand, know about or can anticipate. The precautionary principle must apply to all new technologies. Currently, there is evidence of risk and insufficient evidence of safety with nanotechnology and its processes and products. Caution should also apply when we consider the design, handling, transport, usage and waste products the nanotechnology industry is already producing.

Testing must be on a case-by-case basis. We need to appreciate fully the potential consequences of applying nanotechnologies and their products. The not necessarily substantiated claims of benefits made by proponents of this technology must be balanced against the effects on economies, and public and environmental health and safety. There must be societal and independent scientific debate on health and safety, social and ethical issues, intellectual property issues, and over who has control of the technologies.

Various NGOs have called for the following actions in respect of nano-products[46]:

- A moratorium;
- A withdrawal of nano-products already on the market for substantive safety testing and impact assessment to be carried out by independent scientists;
- An independent case-by-case examination of all proposed developments and releases;
- Independent monitoring of developments; and
- In depth risk assessments.

45 In email correspondence to PSGR.
46 The ETC Group http://www.etcgroup.org/fr/node/14. Friends of the Earth http://nano.foe.org.au/node/95.

There are also calls for establishing a Nanotech Protocol in line with the Biosafety Protocol, an inter-governmental framework that would allow for the monitoring and evaluation of new technologies as they evolve from initial scientific discovery to possible commercialization.[47]

There should be a community-elected, international body with the mandate to track, evaluate, and accept or reject all new technologies and their products; in principle, along the lines of the long-term strategy proposed in 2005 by ETC Group to address the introduction of significant new technologies. ETC maintains a generic, transparent facility could earn the confidence of governments and society as well as of the scientific community. For the purpose of discussion, ETC called the new facility ICENT (International Convention for the Evaluation of New Technologies), a legally binding United Nations Treaty. It would provide a system capable of monitoring any significant new technology.[48]

Individuals and NGOs are urged to take action. A report from Friends of the Earth Canada said:

"Following moves in the United Kingdom and Australia, Canada has taken action to ban the use of manufactured nano-materials and nanotechnology in organics. The Organic and Non-GMO Report reveals that an amendment was added to Canada's national organic rules banning nanotechnology as a 'Prohibited Substance or Method.'"[49]

If labelling becomes mandatory for any product using nanotechnology or containing manufactured nano-particles, consumers can chose not to purchase that product.

For what New Zealanders can do see Addendum Three.

In conclusion

Any potential gains from nanotechnology have to be balanced against risks. Additionally science is increasingly being privatised, and patents on nano-scale technologies are increasing annually at a rapid rate. What will be the outcome? We simply do not know. That alone is reason enough to apply the precautionary principle and insist on urgent regulation, control and safety testing. There is a critical need for nano-specific regulations, eco-responsible design, handling, transport, usage and disposal of intentionally manufactured nano-materials, on national and international levels.

Physicians and Scientists for Global Responsibility New Zealand Charitable Trust
May 2014

Reviewed by Dr Rye Senjen, activist and researcher. Dr Senjen has been involved in a variety of issues over the last 30 years and is internationally known for her work on nanotechnology.

[47] 'A Framework Convention for Nanotechnology?' Abbott, Marchant and Sylvester http://www.eli.org/sites/default/files/docs/article_2011_10_36.10931.pdf and 'Nanotechnologies and Food' http://ihcp.jrc.ec.europa.eu/our_activities/nanotechnology/Nano_Food.
[48] ICENT? www.waccglobal.org/en/20062-communicating-with-angels-being-digital-being-human/578-What-is-the-International-Convention-for-the-Evaluation-of-New-Technologies.html
[49] The Organic and Non-GMO Report, Volume 10, Issue 5 May 2010 http://www.non-gmoreport.com/ArchivesTwo/org&nongmo_may10.pdf; http://nano.foe.org.au/canada-bans-nano-organics

Addendum One

Developments in control and regulation of nanotechnology and its products

Global – See Nanotechnology and International Law Research Guide, published May/June 2014, http://www.nyulawglobal.org/globalex/Nanotechnology_International_Law.htm

Europe – In 2012, ObservatoryNANO said European countries were pursuing their own specific initiatives. Developments for regulation and standards subsequently include:

- 2013 Developments in Nanotechnology Regulation in Europe
  Current product-specific regulations tend to be focused on safety assessment and disclosure and use the broad definition of nanomaterials adopted by the European Commission (the Commission) in 2011as a starting point.
  http://www.reachpsforum.eu/files/Uploads/Documents/REACH/Developments_in_Nanotechnology_Regulation_in_Europe.pdf

- Nano-sciences, Nanotechnologies, Materials and New Production Technologies
  Developments in Nanotechnologies Regulation and Standards - 4 April 2012, the last report of a series developed during four years of the EU FP7 project ObservatoryNANO.
  www.observatorynano.eu
  http://www.observatorynano.eu/project/ keywords "regulations" and "standards"
  http://www.observatorynano.eu/project/filesystem/files/ObservatoryNano_Nanotechnologies_RegulationAndStandards_2012.pdf

- European Commission Recommendation on the definition of nano-material
  http://ec.europa.eu/environment/chemicals/nanotech/pdf/commission_recommendation.pdf

  Updated European Commission regulatory review on nano-materials
  http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0572:FIN:en:PDF

  Commission Regulation (EU) No 344/2013, 4 April 2013
  http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:114:0001:0059:EN:PDF

  European Commission recommendation for Responsible Research and Innovation
  http://ec.europa.eu/research/science-society/document_library/pdf_06/options-for-strengthening_en.pdf.

  Ongoing review of the application of chemical legislation to nano-materials
  http://ec.europa.eu/enterprise/sectors/chemicals/documents/reach/index_en.htm#h2-5

- European Union Regulation 1169/2011 (25 October 2011) on the provision of food information to consumers considerably changes existing legislation on food labelling including:

  Page 9 definition 'engineered nano-material' means any intentionally produced material that has one or more dimensions of the order of 100 nm or less or that is composed of discrete functional parts, either internally or at the surface, many of which have one or more dimensions of the order of 100 nm or less, including structures, agglomerates or aggregates, which may have a size above the order of 100 nm but retain properties that are characteristic of the nano-scale.
  Page 19, List of ingredients: All ingredients present in the form of engineered nano-materials shall be clearly indicated in the list of ingredients. The names of such ingredients shall be followed by the word "nano" in brackets.
  http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011R1169:EN:NOT

- Questions and Answers on the application of the Regulation (EU) N° 1169/2011 – see 2.7.1. http://ec.europa.eu/food/food/labellingnutrition/foodlabelling/docs/qanda_application_reg1169-2011_en.pdf

- Challenges of Regulation and Risk Assessment of Nano-materials http://www.enpra.eu/LinkClick.aspx?fileticket=vNdbj9LmMxo%3D&tabid=58

- Achievements in the work on standards (ISO TC 229) Nanotechnologies http://www.iso.org/iso/iso_technical_committee?commid=381983

- Activities of the OECD Working Party on Manufactured Nano-materials ENV/JM/MONO(2013)2, 13 February 2013 http://search.oecd.org/officialdocuments/displaydocumentpdf/?cote=env/jm/mono%282013%292&doclanguage=en

- Safety of manufactured nano-materials http://www.oecd.org/env/ehs/nanosafety/publicationsintheseriesonthesafetyofmanufacturednanomaterials.htm

- International Cooperation on Cosmetic Regulation (ICCR) - May 2013 http://www.fda.gov/Cosmetics/InternationalActivities/ConferencesMeetingsWorkshops/InternationalCooperationonCosmeticsRegulationsICCR/default.htm

- 'Guidance on the safety assessment of nano-materials in cosmetics' European Commission, 2012, http://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_s_005.pdf

Great Britain - Press release (12 November 2008), Royal Commission on Environmental Pollution: "Urgent action needed on the testing and regulation of nanotechnology." It came out with the 27th UK Royal Commission Report which contained topics it felt could be covered; e.g., "waste issues: some products containing novel materials have a short lifespan and may not be recyclable."

- Royal Commission on Environmental Pollution, Twenty-seventh Report Novel Materials in the Environment: The case of nanotechnology, November 2008 http://www.official-documents.gov.uk/document/cm74/7468/7468.pdf

- The Environmental Permitting (England and Wales) Regulations 2010 http://www.legislation.gov.uk/ukdsi/2010/9780111491423/contents

- UK Nanotechnology Strategy http://webarchive.nationalarchives.gov.uk/+/interactive.bis.gov.uk/nano/

France - Final inter-ministerial Decree (No. 2012-232; effective 1 January 2013) for annual mandatory reporting of marketed "nano-particulate substances" defines "substance with nano-particle status" as:

- [A] substance as that defined in Article 3 of the Regulation (EC) No 1907/2006, intentionally manufactured to a nano-metric scale and containing particles in an unbound state or as an aggregate or as an agglomerate and where, for a minimum proportion threshold of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100 nm. In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the minimum proportion of number size distribution threshold can be reduced. http://www-01.ibm.com/procurement/esi/commodity/esireg.nsf/0/a0a6e1856600b47900257ad1005c560f/$FILE/decret_ENG.pdf

United States - The 2009 Nano-material Research Strategy released by its EPA talks about "the challenge for environmental protection" and "unintended consequences of exposures to humans and ecosystems" and detecting, monitoring, controlling and cleaning up pollution. It wants to also look at preventing and mitigating risks. It directed the federal National Nanotechnology Initiative (http://www.nano.gov/) to coordinate research carried out by designated agencies on nanotechnology and associated issues:

- National Nanotechnology Initiative, Strategic Plan, National Science and Technology Council Committee on Technology, Subcommittee on Nanoscale Science, Engineering, and Technology February 2014 http://nano.gov/sites/default/files/pub_resource/2014_nni_strategic_plan.pdf

- US Nanotechnology Standards Catalogued: Chemistry 07.030: Physics. Chemistry. http://www.document-center.com/standards/ics/07.030.

- Memorandum for the Heads of Executive Departments and Agencies from the White House, Executive Order 13563. 18 January 2011 http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/nanotechnology-regulation-and-oversight-principles.pdf

- US Department of Agriculture, 'Nano-materials in Government Regulations & Programs' http://www.fs.fed.us/research/nanotechnology/nanomaterials.php

- Environmental Protection Agency Control of Nano-scale Materials under the Toxic Substances Control http://www.epa.gov/oppt/nano/

- Nano Materials Research Strategy 2009 www.epa.gov/nanoscience/files/nanotech_research_strategy_final.pdf

- Food and Drug Administration Continues Dialogue on 'Nano' Regulation http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm258462.htm

Japan - regulation is primarily the responsibility of the

- Ministry of Economy Trade and Industry (METI), http://www.meti.go.jp/english/
  Ministry of Environment (MOE) http://www.env.go.jp/en/
  Ministry of Health, Labour and Welfare (MHLW) http://www.mhlw.go.jp/english/index.html
  National Institute of Advanced Industrial Science and Technology (AIST), Japan's largest public research institute, http://www.aist.go.jp/index_en.html

- A 2009 paper from the Research Institute of Science for Safety and Sustainability discusses Japan's nano-materials safety position. In English on http://www.aist-riss.jp/main/?ml_lang=en

China - Nano-science and nanotechnology are major fields of science research, largely depending on still nascent regulatory systems.

- 'Regulation and Governance of Nanotechnology in China: Regulatory Challenges and Effectiveness'. Jarvis and Richmond, European Journal of Law and Technology, Vol. 2, No.3, 2011, http://ejlt.org/article/view/94/155

Addendum Two

Examples of products that must require safety testing before marketing approval, and mandatory, comprehensive labelling

Nanotechnology and public health

'Too small for concern? Public health and nanotechnology' Diana M. Bowman and Michael Fitzharris, Australian and New Zealand Journal of Public Health, Volume 31, Issue 4, pages 382–384, August 2007 DOI: 10.1111/j.1753-6405.2007.00092.x
http://www.parliament.nsw.gov.au/Prod/parlment/committee.nsf/0/bd28803018147668ca25740a007e94ad/$FILE/Submission%201%20-%20Attachments.pdf

> Abstract: "While advances in nanotechnology promise to deliver significant benefits to many aspects of health care, there is increasing concern that regulatory regimes do not adequately capture the potential risks associated with this new technology. Concerns have arisen due to preliminary evidence suggesting that some engineered nano-particles may display undesirable toxicological properties, presenting potential risks to human and environmental health and safety."

Nanotechnology and cosmetics

'Sunscreen Safety: The Precautionary Principle, The Australian Therapeutic Goods Administration and Nano-particles in Sunscreens', Faunce et al., 2008, 2:231–240 DOI 10.1007/s11569-008-0041-z.
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1402996

> Abstract: "This paper seeks to explore to what extent the precautionary principle should have been and was in fact utilized by the Australian Therapeutic Goods Administration (TGA) in its decision to approve the marketing of sunscreens containing titanium dioxide (TiO2) and zinc oxide (ZnO) in nano-particulate form. In particular, this article assesses to what extent better application of that principle might have altered the TGA's decision that TiO2 and ZnO ENPs in sunscreens do not require new safety testing, because they are functionally equivalent to their bulk counterparts."

Nanotechnology and medical products

'Toxicological and public good considerations for the regulation of nano-material-containing medical products', Expert Opin., Faunce T A, Drug Saf. 2008 Mar;7(2):103-6. doi: 0.1517/14740338.7.2.103;
http://www.ncbi.nlm.nih.gov/pubmed/18324873.

> Abstract: Of significant consideration was "the relative paucity of metrological and toxicological data."

Addendum Three

What can the New Zealand public do?

Gather information:

- Become informed
- Demand full disclosure on labels

Make a submission

- Make a submission when a local council tackles the issue of waste. A submission form should be available on a council's website and that website is on http://www.lgnz.co.nz/lg-sector/maps/

Monitor developments on websites such as:

- The Sustainability Council of New Zealand http://www.sustainabilitynz.org/nanotechnology/
- Food Standards Australia New Zealand – Nanotechnology and Food http://www.foodstandards.govt.nz/consumerinformation/nanotechnologyandfoo4542.cfm
- Consumer www.consumer.org.nz/reports/nanotechnology
- Ministry of Business, Innovation and Employment – Science and Innovation http://www.msi.govt.nz/. Enter 'whole site' in Search and 'nanotechnology' in Subject
- See List of nano-materials notified to the New Zealand EPA, http://www.epa.govt.nz/hazardous-substances/approvals/group-standards/Pages/List-of-nanomaterials-notified-to-the-EPA.aspx
- See 'A Nanotechnology Initiative for New Zealand' involving the Institute of Geological and Nuclear Sciences, Industrial Research Limited, the universities of Massey, Canterbury and Victoria through the partnership of the MacDiarmid Institute for Advanced Materials and Nanotechnology, http://macdiarmid.live.egressive.com/sites/macdiarmid.live.egressive.com/files/common/finalintro_web.pdf
- Industrial Research Limited (a Crown Research Institute) http://www.irl.cri.nz/search/node/nanotechnology
- See 'An Evaluation of Whether New Zealand's Occupational Health and Safety Law Adequately Addresses the Risks to Workers Exposed to Nanotechnology and Nano-particles' 2013, New Zealand Journal of Employment Relations 37(1): 100-117, Dr Jennifer Moore, Research Fellow in the Faculty of Law, University of Otago, barrister and solicitor of the New Zealand High Court. www.sustainabilitynz.org/wp-content/uploads/2013/03/Moore_AreNZWorkplaceLawsNanosafe.pdf
- For safety of manufactured nano-materials the Ministry for the Environment website refers enquirers to 'Safety of manufactured nano-materials' published by the Organisation for Economic Co-operation and Development (OECD) http://www.oecd.org/env/ehs/nanosafety/

- New Zealand signed the Convention founding the OECD in 1973 and maintains a permanent delegation to the OECD. http://www.oecd.org/newzealand/ and http://www.oecd.org/general/searchresults/?q=nanotechnology&cx=012432601748511391518:xzeadub0b0a&cof=FORID:11&ie=UTF-8

- NanoSafe Australia - a research network of toxicologists and risk assessors to address occupational and environmental health and safety of nano-materials, http://www.rmit.edu.au/nanosafe

- See 'Engineered nano-materials: Investigating substitution and modification options to reduce potential hazards'. Jackson N, Tepe S and Wright P; RMIT University. Safe Work Australia, 1 August 2010; ISBN 978-0-642-33100-7 http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/rp201008engineerednanomaterialsinvestigatingsubstitutionandmodification

- See 'Engineered nano-materials: Evidence of the effectiveness of workplace controls to prevent exposure', Jackson N, Lopata A, Elms T and Wright P; RMIT University). Safe Work Australia, 4 November 2009; ISBN: 978-0-642-32884-7 http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/rr200911enevidenceoneffectiveness

Further information is available at:

- Centre for Responsible Nanotechnology www.crnano.org

- Nature www.nature.com

- Science News Online www.sciencenews.org

- The Virtual Journal of Nanoscale Science & Technology www.vjnano.org

- Science Magazine www.sciencemag.org

- The ETC Group www.etcgroup.org/

- ICON – International Council on Nanotechnology http://icon.rice.edu/

- Friends of the Earth http://nano.foe.org.au/search/node/nanotechnology

- Greenpeace http://crnano.org/Greenpeace.htm

Footnote: Are microfibers a product of nanotechnology?

Microfibers are made by taking nylon fibres and forcing them through a tiny pipe. These are then heated and fused. The fused fibres are split into microfibers one hundred times thinner than a human hair. This makes each fibre one micrometer (one micron) in diameter or smaller. This is *micro*technology, not *nano*technology. Micron-sized fibres are about 1000 nanometres wide.[50]

[50] www.explainthatstuff.com/microfibercloths.html