Journal of Organic Systems 2008 3(1) 3-22

Archived at https://orgprints.org/13569

NANOTECHNOLOGY: THE NEXT CHALLENGE FOR ORGANICS

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Abstract

Nanotechnology is the fast growing science of the ultra small; it is creating engineered particles in the size range 1 to 100 nanometres. At this size, materials exhibit novel behaviours. Nanotechnology is a rapidly expanding multibillion dollar industry, with research being heavily promoted by governments, and especially the US. Nanoscale materials are already incorporated into more than 580 consumer products, including food, packaging, cosmetics, clothing and paint. Nanotechnology has been cited as the foundation of a new "advanced agriculture". This technology is advancing without nano-specific regulation and without labelling, while at the same time, public confidence in government regulatory agencies, and in the safety of the food supply, is declining. There is an opportunity, perhaps an imperative, for the organic community to take the initiative to develop standards to exclude engineered nanoparticles from organic products, just as GMOs have been excluded previously.

Keywords: nanotechnology, nanoparticles, nanoscale materials, nano-pollution, organic agriculture, organic farming, organic food, regulation, labelling, IFOAM, standards.

Introduction

There is a certain frisson about new technologies, and the first flush of such excitement produces a slew of novel and promising products and services.

A century ago, for the health conscious, there was a product: "*Radithor - Certified Radioactive Water*", a concoction of radium and thorium in "triple distilled water" - the label claimed it as being registered with the US Patent Office (Harvie, 2005). For the early twentieth-century agriculturalist, a Scottish company offered "*Radium Fertilizer*", and it promised to be "*Specially Useful for Vegetables Fruits and Flowers*" (Harvie, 2005). With this early gush of enthusiasm for this promising new science of radiation, X-rays were touted as "*an absolutely painless method of epilation*" (Freund, 1899, cited by Collins, 2007, p. 68; Herzig, 1999). "*Tens of thousands of women … were exposed to massive doses of radiation on their faces and arms*" (Collins, 2007, p. 69). Unwanted feminine facial and bodily hair was a problem no longer, X-rays truly did make your hair fall out. Then with the growing dawning of the seriousness of the side effects of this radiation-depilation, and "*With the prospect of being sued for millions of dollars, The Trico Sales Corporation collapsed ... By 1970 researchers were attributing over one-third of radiation-induced cancers in women to X-ray hair removal"* (Collins, 2007, p. 69).

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From the outset, radiation was a promising, exciting and fascinating technology. Very soon there was a quest for commercial opportunities. Some of these opportunities carried, unbeknown to all, a long and slow burning fuse that would eventually ignite its gunpowder and slay or maim its victims. In this paper the authors raise the questions: might the newly emergent science of nanotechnology carry with it, also, a slow burning fuse, ought we meet the first flush of ebullience with a second flush of precaution, and, in any event, how might the organic food and agriculture sector respond to this latest technology, which we can probably agree is promising, exciting and fascinating?

Organic Context

Organic agriculture was originally conceived as a response to artificial fertilisers, pesticides, and the industrialization of farming (Steiner, 1924; Northbourne, 1940). Since then the organic community has responded to the challenge of emergent technologies that potentially may usurp the integrity of organic philosophy and practice. Two examples of such techno-challenges have been radioactivity and genetically modified organisms (GMOs). In both cases the response has been to exclude these promising new technologies from the production processes of certified organic produce.

The organic movement is at the forefront of efforts to protect the world's food supply from invasive technologies. So any emerging threat to the purity and integrity of our food supply is of core salience to the organic community, deserves attention, and warrants action. Is nanotechnology just such an emerging threat?

Drexler's Nanotechnology

Nanotechnology has been heralded with enthusiasm: *"the astonishing new science that will transform the world"* (Regis, 1995, cover); "*nanotechnology will change the future of your business"* (Uldrich & Newberry, 2003, dustjacket).

In 1986 Eric Drexler introduced a world readership to the concept of nanotechnology *via* his book "Engines of Creation", and followed up with a technically more detailed account "Nanosystems: Molecular Machinery, Manufacturing and Computation" (1992). He wrote: "Arranged one way, atoms make up soil, air and water, arranged another, they make up ripe strawberries" (Drexler,1986, p. 3). His ideas were, and remain, bold and innovative, and they attracted some ridicule. "The laws of nature leave plenty of room for progress" (Drexler, p. 4), and with this as a starting point, Drexler went on to describe machines so small that they could assemble atom by atom. This for Drexler was the essence of nanotechnology. Life itself was the proof-of-concept: "Ribosomes are proof that nanomachines built of protein can be programmed to build complex molecules" (p. 8), and "the T4 virus is but one of many self-assembling structures" (p. 9). In another age, Drexler might have been a science fiction writer. As it is, his vision has borne fruit, but very different from the vision he portrayed two decades ago.

Drexler (1986, p. 39) asked: "*What is possible, what is achievable, and what is desirable?".* He was optimistic: "*We can both heal Earth and protect it"* (p. 123). On the flip side, he foresaw three impediments to his bold vision: "*Evil - are we too wicked to do the right thing? Incompetence - are we too stupid to do the right thing? Sloth - are we too lazy to prepare?"* (p. 200).

More than 20 years on, there are no Drexler self-replicating machines, and no nanobots to go out of control creating a "grey goo" world. Perhaps because of his optimism and the science fiction feel of Drexler, in the shadow of his perhaps fanciful vision has grown a

 ISSN 1177-4258

nanotechnology industry of very low public visibility, and little or no government oversight.

While there is "no globally recognized definition" of nanotechnology (Roco, 2007a, p. 3.2), there are nevertheless many definitions and they exhibit a high degree of congruence. Nanotechnology has been defined as: *"the understanding and control of matter at dimensions of roughly 1 to 100 nanometers (a nanometer is one-billionth of a meter), where unique phenomena enable novel applications*" (Marburger, 2007, p. 3). Roco (2007a, p. 3.2) makes the point that a definition needs to address three issues: "*the size range*", "*the ability to measure and restructure matter*" and "*exploiting properties and functions specific to nanoscale as compared to the macro- or microscales; this is a key motivation for researching nanoscale"*.

The *Australian Office of Nanotechnology* offers the following definition: *"Nanotechnology is the precision-engineering of materials at the scale of 10^{-9} metres (one ten-thousandth the breadth of a human hair), at which point, new functionalities are obtained, resulting in products, devices and processes that will transform various industries"* (AON, 2007).

Terminology and Scale

Nanotechnology is a rapidly developing domain of research and practice, the terminology is in a state of flux (NNCO, 2006) and usage is evolving. In this paper, the terms nanoparticles, nanomaterials and nanoscale materials are used interchangeably to refer to engineered nanoscale materials whatever their form - and includes nanotubes, nanowires, fullerenes, quantum dots *et alia*. Nanoparticles are a heterogeneous group of materials exhibiting a wide variety of shapes, surface areas, chemical properties, reactivity and toxicity. They have in common their smallness, that they are engineered in the size range 1 - 100 nanometres (a nanometre is one billionth of a metre; 1 nm = 10^{-6} mm = 10^{-9} m). (In this paper the authors have adopted the European spelling of *metre* and *nanometre*; however the US usage of *meter* and *nanometer* are retained where they are thus spelt within quotations). Nanotechnology is developing both "nanoscale versions of existing materials, [and] entirely new classes of materials" (NNCO, 2006, p. 1). There has been a call to regard particles up to 300 nm as nanomaterials (Miller & Senjen, 2008).

By way of comparison, animal cells are typically in the range 10,000 nm to 20,000 nm (10 to 20 micrometers, Alberts *et al*., 1989). A single molecule of water has a diameter of approximately 0.275 nm (2.75 angstroms, Chaplin, 2008). A light microscope can resolve details down to a limit of 200 nm, an electron microscope down to 0.1 nm (Alberts *et al*., 1989), and hence particles in the 1 - 100 nanometre range are not visible using a light microscope, but are amenable to electron microscopy.

The essence of nanotechnology is scale. As the size of particles is reduced, the relative surface area is increased - this can lead to achieving the same amount of reactivity and bioactivity for a lesser quantity of agent. For a given quantity of material, if the linear dimensions of particles are *decreased* by a factor of *x,* then the total surface area is *increased* by a factor of *x*. (A cube of dimension 10 x 10 x 10 has a volume of 1000 cubic units and presents a surface area of 600 square units; compare this to 1000 cubes of dimension 1 x 1 x 1 which likewise have a volume of 1000 cubic units, but present a total surface area of 6000 square units, a ten fold increase). So, for example, if particles in a given mass of material are uniformly reduced from micrometre size to nanometre size, the total surface area will be increased by a factor in the order of 1,000. Likewise, if particles are reduced from millimeter size to nanometre size, the total surface area for the same mass of material will be increased by a factor in the order of 1,000,000.

Same but Different

Nanotechnology proponents, following in the footsteps of the GMO industry, have adopted a two-handed advocacy stratagem of: *same but different*. In presenting to investors and the patent office, the emphasis is on "different": here is a material that has unique qualities and behaviours because of its nano-smallness, and it is worthy of investment dollars and it qualifies, by virtue of its novelty, for patenting. On the other hand, in presenting to regulators, the claim is "sameness", that nano versions of chemicals that are already approved for use, need attract no further scrutiny or regulation since they are the same chemical. The consequence of this two-handed ploy is that there are many patents (ETC Group, 2004; Roco, 2007a), but regulation specific to nanotechnology is lacking (Bowman & Hodge, 2007; Miller & Senjen, 2008).

Cornwall and Featherstone (2004) report that size is "likely patentable" in a variety of jurisdictions provided that this generates unpredictable or unexpected results or effects. Pacific Corporation (Korea) (2003, p. 1) have patented nanoscale ginseng which they claim achieves "enhanced skin penetration" for anti-aging preparations. The Coalition Against Biopiracy (CAB, 2004, p. 2) awarded Yang Mengjun (China) their accolade for "Worst Nanopiracy" for "securing 466 patents on nanoscale versions of traditional medicinal herbs by simply turning traditional plants into fine powders with particles under 100 nanometres". The European Patent Office (EPO, 2008) database lists 959 patents to Yang Mengjun, and a large family of these patents are of the form "*Nano medicine 'x' and its preparing process*". Examples include "*Nano medicine "Shengli" and its preparing process*" Mengjun, 2002a) and "*Nano medicine "Shuxinjangzhi" and its preparing process*" (Mengjun, 2002b).

Patent activity contrasts with the approach of the US Environmental Protection Agency (EPA, 2008a) which has recently launched the Nanoscale Material Stewardship Program (NMSP) in which "Participants are invited to voluntarily report available information on the engineered nanoscale materials they manufacture, import, process or use". The EPA states the intention of reporting results "after approximately two years" and then determining "the future direction of … reporting". For the purposes of the Toxic Substances control Act (TSCA) the EPA (2008b, p. 5) "has not used particle size to distinguish substances that are known to have the same molecular identity" and the agency intends to continue this approach with nanoscale materials.

The municipal council of the City of Berkeley, California appears to be the first legislature to create nano-specific regulations. The regulations apply only within the shire. The local hazardous material code was amended, effective 15 December 2006. It applies to "manufactured nanoparticles", which are defined as particles "with one axis less than 100 nanometers in length" (Heartney & Carlton, 2007, p. 2). The code requires that "All facilities that manufacture or use manufactured nanoparticles" be subject to disclosure rules where they must specify details including toxicology of the materials, containment and disposal procedures. Disclosure is mandated "regardless of the quantity of nanoparticles involved" (p. 2). The City Council of Cambridge, Massachusetts, is reported to be examining the Berkeley regulations as a model that they may also adopt (p.4). According to Heartney & Carlton (2007, p. 4) this raises "the specter of a proliferation of local legislation regulating nanotechnology".

The City of Berkeley response to nanotechnology and potential nano-pollution has attracted some muddled approbation from Monica, Heintz & Lewis (2007). They state that "all nano-companies in Berkeley will now have to carefully evaluate their own possible workplace exposure and take appropriate steps to address these issues" (p. 69). They cite, with apparent approval, the nano-safety industry goals proposed by

ISSN 1177-4258

Maynard *et al.* (2006, p. 268), to "Develop instruments to access exposure to engineered nanomaterials in air and water, within the next 3 - 10 years" and to "Develop and validate methods to evaluate the toxicity of engineered nanomaterials within the next 5 - 15 years". The Monica *et al*. (2007) critique of the Berkeley response to nano seems to be more about the risk stance of the parties than their so called "perils of pre-emptive regulation" (p. 68). They acknowledge that the City of Berkeley has adopted a precautionary approach, whereas Monica *et al*. appear to be recommending a postcautionary approach.

Worldwide government expenditure on nanotechnology research and development in 2006 was US$4.681 billion (Roco, 2007a, 3.12; Fig. 1). The US President's 2008 budget request is for US$1.444 billion in government research funds for nanotechnology, with the stated goal being to "facilitate transfer of new technologies into products" (Marburger, 2007, p. 3). For the U.S. Department of Agriculture (USDA) this includes "*devices and systems (including those that are wearable, implantable and portable), for biological processes critical to agriculture production, food safety and quality, agricultural biosecurity, and human health … food and agriculture product identity tracking and preservation… [and] to utilize these new capacities to address some of the most challenging issues facing agriculture and foods*" (Marburger, p. 17).

According to Carafano & Gudgel (2007, p. 3) "*The U.S. is currently the world leader in nanotechnology … Total US public and private spending on nanotechnology research and development totals about $3 billion annually, or one-third of the estimated $9 billion spent worldwide*". The suggestion is that, worldwide as well as in the US, private expenditure on nanotechnology meets, or exceeds, that expended by government.

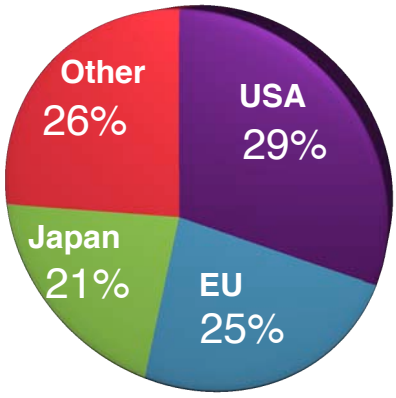


Figure 1. Distribution of US$4.681 billion worldwide government R & D expenditure on Nanotechnology in 2006. USA: US$1.351 billion; EU US$1.150 billion: Japan US$980 billion; Other US$1.200 billion. Data source: Roco, 2007a.

The founder of the US *National Nanotechnology Initiative* (NNI), Mihail Roco (2007b, p. 9) declares that: "*Creating a chorus to support nanotechnology, from 1990 to March 1999, was an important preliminary step in moving the profile of nanotechnology from 'dormant' to recognition of it as an opportunity of 'immense' potential"*. Roco (2007a, p. 3.6) reports that "*a main challenge was the search for the relevance of nanotechnology. We had to overcome three waves of skepticism … limited relevance … concern of large and unexpected consequences… [and] concerns … on environmental, health and safety (EHS) implications"*. The initial strategy was one of "*communicating the vision to large*

communities and organizations" (p. 3.7). *"In 2000, we estimated a $1 trillion nanotechnology-related market of nanoproducts incorporating nanotechnology … We also saw the increasing convergence of nanotechnology with modern biology"* (p. 3.9). Now, *"Research is advancing toward systematic control of matter at the nanoscale faster than envisioned"* (p. 3.11). *"All major science and engineering colleges in the U.S. have introduced courses related to nanoscale science and engineering"* (p. 3.13). Roco reports triumphantly that "*in January 2006 … President Bush listed nanotechnology as a top technological opportunity for national competitiveness" (*p. 3.20). An upcoming challenge is "*Expansion into new areas of relevance* such as ... *food and agriculture"* (p. 3.21).

Nano-Products

In a recent inventory of consumer nanotechnology, 580 products were identified, and classified into eight categories (WWICS, 2007a; Fig. 2). Products in the inventory were selected "solely based on information that can readily be found on the internet … all entries can be validated by anyone with internet access" (WWICS, 2008). Consumer products already in the market include a "100% Cotton Sheet Set", impregnated with nanoparticles. The advertising blurb declares that: *"when the nano-silver comes in contact with bacteria and fungus it will adversely affect cellular metabolism and inhibit cell growth. The nano-silver suppresses respiration, basal metabolism of electron transfer system, and transport of substrate in the microbial cell membrane"*. Of the total of 580 nano-products, 11.6% (n = 67) were classified as *Home and Garden*. The largest category was products classified as *Health and Fitness,* and accounted for 61.4% (n = 356) of the total.

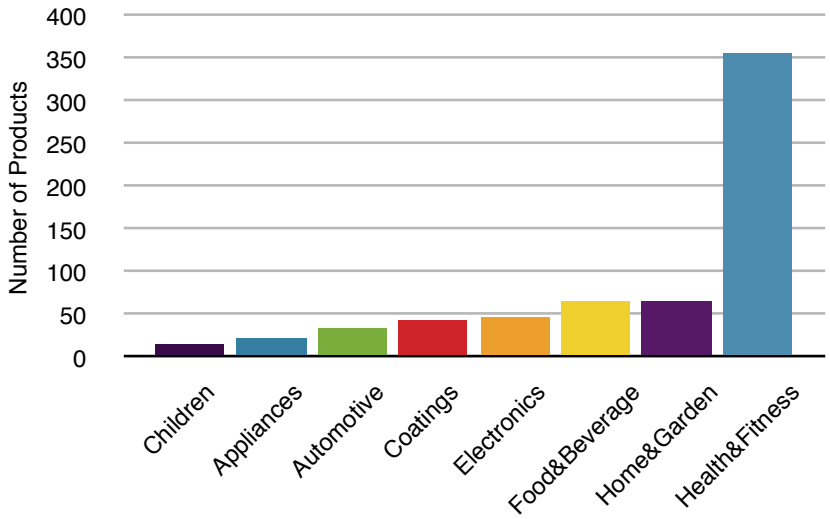


Figure 2. Products incorporating nanotechnology currently in the market, N = 580. Note: some products are attributed to more than one category. Data source: WWICS (2007a).

The nanoproduct *Slim Shake Chocolate* is pitched at health conscious consumers. The product is described as being: "Low in fat and calories", "No artificial sweeteners" and with the added promise: "Tastes delicious". The promotional text advises that this chocolate drink contains "CocoaClusters™" - "The natural benefits of cocoa have now been combined with modern technology to create CocoaClusters. RBC's NanoClusters

ISSN 1177-4258

are tiny particles, 100,000th the size of a single grain of sand, and they are designed to carry nutrition into your cells" (O'Connor, 2006). This nanofood product is available for ordering *via* the internet from a USA address.

Food and Beverage accounted for 11.4% (n = 66) of the total (WWICS, 2007a). These products were further subdivided as *Food* (5% of the *Food and Beverage* category), *Cooking* (14%), *Storage* (23%), and *Supplements* (58%), (Fig. 3). The three food nano-products were: a canola oil, the chocolate slim shake drink (described above), and a new twist on an old beverage - *Nanotea*. The *Cooking* category includes anti-bacterial utensils, cutlery, chop sticks and cookware. *Storage* included plastic beer bottles, *Miracle Food Storage* plastic bags and containers, plastic food wrap, and a baby's mug and milk bottle. The *Daewoo* Refrigerator claims: "*Nano silver presents strong disinfection, deodorant and storage power. It also maintains balance of hormone within our body and intercepts electromagnetic waves significantly*" (WWICS, 2007a).

Friends of the Earth (Miller & Senjen, 2008, p. 3) have since identified 104 agriculture and food chain products "now on sale internationally" that incorporate nanotechnology, and they state that "we believe this to be just a small fraction of the total number of products now available worldwide".

Major food and beverage corporations are investing in nanotechnology. This includes Nestle, Kraft, Unilever, PepsiCo, General Mills, Campbell Soup, McCain and Goodman Fielder (ETC Group 2004, p. 63). Is resistance futile? Will engineered nanoparticles infiltrate agricultural landscapes and food systems in the wake of profit-driven farm-to-plate industrialisation - with substantial governmental encouragement and research investment, but without public scrutiny, either local or global?

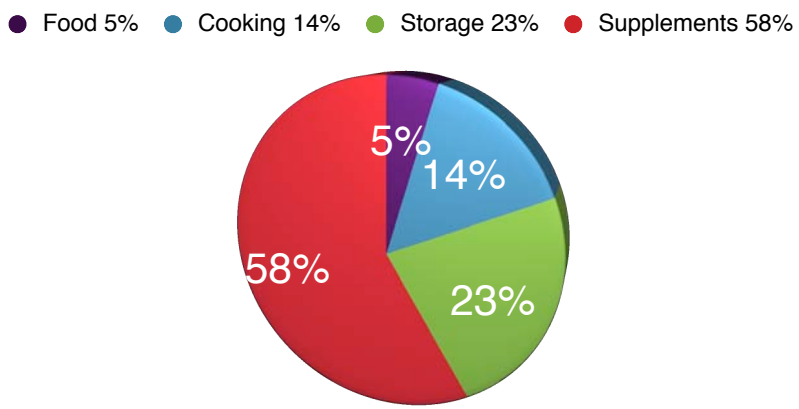


Figure 3. Distribution by sub-category of nanotechnology products classified as *Food and Beverage*, n = 66. Data source WWICS (2007a).

Nano-Uncertainties

Carafano & Gudgel (2007, p. 3) observe that "Unlike in other industries such as biotechnology, there is no legal framework to guide responsibility and liability in nanotechnology". They state that "concerns with … the possible toxicity of nanoparticles and their potential to self-replicate" are "driving away many potential investors and companies".

Nanotechnology is currently operating in a '"regulatory vacuum" (ETC Group, 2004, p. 48). Worldwide there is an absence of nano-specific legislative regulation or control (RS & RAE, 2004; Bowman & Hodge, 2007; Beggin & Pendergrass, 2007; Miller & Senjen, 2008). "That there is no regulatory oversight is chilling", state Miller & Kinnear (2007, p. 56).

Emphasising the uncertainty of nano-safety, the US EPA Nanotechnology White Paper (EPA, 2007, p. 78) reported that:

> "*… nanoparticle toxicity is complex and multifactorial, potentially being regulated by a variety of physiochemical properties such as size, chemical composition, and shape, as well as surface properties such as charge, area and reactivity. As the size of particles decreases, a resulting larger surface-to-volume ratio per unit weight for nanoparticles correlates with increased toxicity as compared with bulk material toxicity. Also as a result of their smaller size, nanoparticles may pass into cells directly through cell membranes or penetrate the skin and distribute throughout the body once translocated to the circulatory system. While the effects of shape on toxicity of nanoparticles appears unclear, the results of a recent* in vitro *cytotoxicity study appear to suggest that single-wall carbon nanotubes are more toxic than multi-wall carbon nanotubes. Therefore, with respect to nanoparticles, there is concern for systemic effects (e.g. target organs, cardiovascular, and neurological toxicities) in addition to portal-of-entry (e.g. lung, skin, intestine) toxicity*".

Once released there is no mechanism for the recall of nanoparticles. Their fate in the environment is unknown (Breggin & Pendergrass, 2007). Their capacity for bio-accumulation, bio-excretion, and the health ramifications for humans and other species, remain open questions.

According to NRDC (2005, p. 6): "*One of the new properties of nano-sized particles is their extreme mobility … If they become airborne, nano particles can float for long periods - unlike larger particles - they do not readily settle onto surfaces … current drinking water filters do not effectively remove nano particles*". Three modes of nano-contamination of food-stuffs are identified in Table 1.

Sources of Nano Contamination of Food	Examples
Adventitious	Nano-pollution from: airborne, rain-borne, water-borne nanoparticle-drift from off-farm and/or off-site.
Incidental	Nano-pollution from: nanonized packaging; surface coatings including paint - in packaging, sorting, storage, sales areas; utensils; packaging equipment; transport equipment; filtration equipment.
Intentional	Nano-pollution from: nanonized production inputs; food processing additives; foliar or systemic sprays.

Table 1. Three sources of potential nano-contamination of food.

ISSN 1177-4258

The safety of nanotechnology has not been thoroughly researched, and scant toxicological results are available. The US Environmental Protection Agency (2007) identifies a "paucity of data" (p. 52) and "a high degree of uncertainty" (p. 53) regarding the safety and toxicity of nanoscale materials. According to the Royal Society and the Royal Academy of Engineering: "*There is virtually no evidence available to allow the potential environmental impacts of nanoparticles and nanotubes to be evaluated"* (RS & RAE, 2004, p. 80). The UK's Department of Environment, Food and Rural Affairs report "a widespread lack of evidence of research on human health aspects of nano-materials" (DEFRA (2007, p. 7).

Responding to this lack of data, Maynard *et al.* (2006, p. 269) have called for the "global research community" to: "Develop models for predicting the potential impact of engineered nanomaterial on the environment and human health, within the next 10 years"; and to "Develop robust systems for evaluating the health and environmental impact of engineered nanomaterials over their life, within the next 5 years".

Hoet, Bruske-Hohlfeld & Salata (2004) note that for both proponents and critics, "*it is extremely hard to argue their case as there is limited information available to support one side or the other*" (p. 1). They point out that because "*human skin, intestinal tract and lungs are always in direct contact with the environment"* they consequently present potential portals, of access to nanoparticles, of respectively 1.5m^2, 140 m^2 and 200 m^2 and thereby present relatively massive ingress opportunities for nanoparticles which are of size 10^{-8} m to 10^{-9} m. Hoet *et al.* (2004) report evidence that nanoparticles can be transported *via* the blood, the lymph, and even by nerve cells. They report that oral intake of nanoparticles led to their deposition in "*the liver, spleen, blood and bone marrow*" (p. 8); they comment that in general "*the health effects of cellular uptake of nanoparticles have not been studied in depth" and that "unintended passage through the BBB [blood brain barrier] is possible*" (p. 9). They conclude that for the purposes of health risk assessment "*each nanomaterial should be treated individually*", they call for "*a database of health risks associated with different nanoparticles"* and they add that *"Nanoparticles designed … as food components need special attention*" (p. 10).

The blood-brain barrier (BBB) protects the brain from the entry of disease and many molecules and drugs. Nanoparticles are reported as breaching this barrier (Saito *et al*., 2005; Costantino *et al*., 2005).

Of the approximately US$1.4 billion dollars spent annually on US Government-sponsored research, a mere 3% is devoted to health and safety (NNCO, 2006). The fundamental questions are only now being formulated, and are far from being answered. Although proponents argue that nanotechnology "will likely be the foundation for achieving widespread benefits, including … advanced agriculture" (NNCO, 2006, p. 1), just what those benefits might be, to whom they might accrue and at what cost and to whom, and just what this *de novo* "advanced agriculture" might be, all remain unanswered questions. Is nanotechnology the new sliced bread, the new snake oil, or the new Pandora's box? - we are all without the required data, and/or the tools, to make such a determination, or even a guesstimate, and although the long litany of known unknowns presented in the NNCO (2006) report might incline a technophile to an invocation of the precautionary principle, the NNCO report makes no mention of such an approach.

Unanswered questions include: "Are current toxicity testing methods appropriate, for assessing the toxicity and potential biological effects of engineered nanoscale materials? … What kinds of human and environmental exposures to nanomaterials can be anticipated and measured? By which paths do nanomaterials move within the

body?" (NNCO, 2006, p. 1). The Canada-based Action Group on Erosion, Technology and Conservation have proposed nano-warning labelling (ETC Group, 2007; Fig. 4). Taiwan has taken a contrary approach, adopting in 2006 a "Nano Mark System" for the voluntary labelling and certification of eight categories of products that contain "nanoingredients", including paint and curtains, but not including a food or cosmetic category (Hsu, 2006).

Figure 4. An entrant from the ETC Group's Nano-Hazard Symbol Contest (ETC Group, 2007).

The US National Nanotechnology Coordination Office advises that there are "No studies on testing the effectiveness of personal protective equipment (PPE) against nanomaterials" (NNCO, 2006, p. 47); "No filtration system can remove completely airborne particles from air streams" (p. 47); "Manufacturing processes may result in releases of nanomaterial to the air, water, or land … Research is also needed to determine if disposal and degradation of consumer products could result in the release of nanomaterials into the environment, requiring attention to landfills, incinerators and recycling facilities" (p. 49). There remains another big unknown shared with other toxic and potentially toxic technologies, the challenge to "determine the best methods for waste disposal" (p. 50).

Ludlow (2007) reports that "current Australian regulation of workplace dangers from chemical exposure based on size is inappropriate for [nanoparticles] NPs" (p. 136) and calls for new regulation to be "in the public's, rather than private, interests" (p. 152).

The health and medical sequelae of inhaling, ingesting or dermally acquiring nanoparticles are unknown. The research to remedy this paucity of data is not a clear priority of the NNI (for example), and in any event, such research is likely to proceed over years and decades, rather than weeks or months; it is likely to be complex and surprising, and if other enviro-toxicological studies of commercial significance are a guide, we can expect it to be contested for decades. As with asbestos, the toxicological fate of nanoparticles can be anticipated to be a function of whether they are free, bound or embedded, as well as how, where, and when the transitions between the free and bound states may occur. Comparisons have already been drawn between asbestos fibres and carbon nanotubes (Ludlow, 2007).

In the absence of data that would enable informed decisions - "There is virtually no evidence available to allow the potential environmental impacts of nanoparticles and nanotubes to be evaluated" (RS & RSE, 2004, p. 85) - The Royal Society and The Royal Society of Engineering have made recommendations, including:

> *"the release of manufactured nanoparticles and nanotubes into the environment be avoided … That factories and research laboratories treat manufactured nanoparticles and nanotubes as if they were hazardous ...That the use of free (that is, not fixed in a matrix) manufactured nanoparticles … be prohibited …*

ISSN 1177-4258

until it can be demonstrated that the potential benefits outweigh the potential risks" (RS & RSE, 2004, p. 85).

Nanotechnology and Public Awareness

Despite the claim of sales of "an estimated $50 billion worth of nanotechnology manufactured goods on the global market last year" (WWICS, 2007b, p. 1; also Hebert, 2007), and the claim that "the United States leads the world" in nanotechnology (Marburger in NNCO, 2006), public awareness of nanotechnology is low. In a US national survey of 1,014 adults (HRA, 2007), 71% of respondents professed to know little or nothing about nanotechnology (Fig. 5), and 51% of respondents indicated uncertainty over the risks *versus* benefits (Fig. 6;). Sixty one percent of respondents declared that food in general was less safe now than five years ago (Fig. 7). Public confidence in food regulatory bodies is declining (Fig. 8). Twenty nine percent of respondents declared they would not purchase nano-enhanced food, and 62% indicated they would need more information before doing so, and only 7% indicated a willingness to purchase such food (Fig. 9). Because there is no regulation and no labelling requirements, these nay-sayers may nevertheless, inadvertently, be nano-consumers.

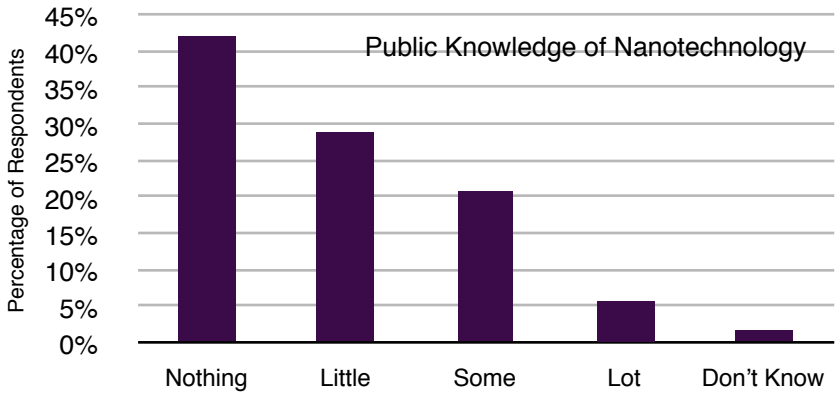
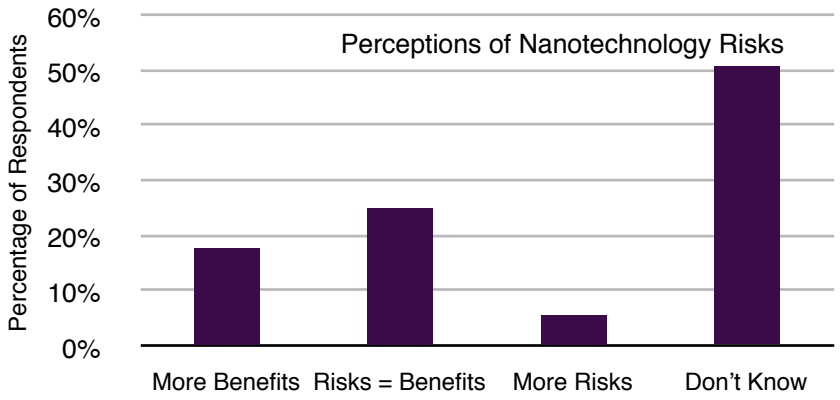


Figure 5. Public awareness of nanotechnology, Respondents were asked "Have you heard much about nanotechnology?", N = 1 014. Data source: HRA, 2007.



. **Figure 6. Respondent's "Initial impression of risks and benefits of nanotechnology", N = 1014. Data source: HRA, 2007.**

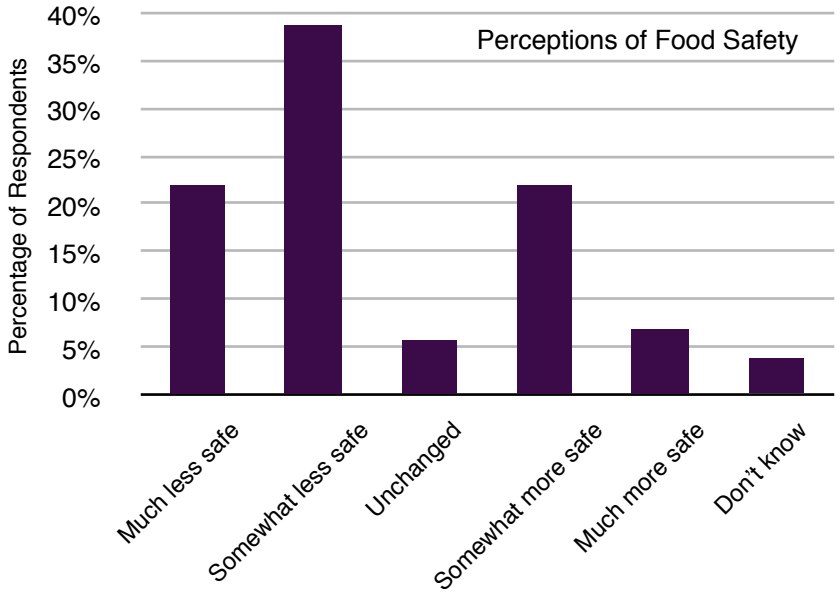


Figure 7. Percentage of respondents completing the sentence: "Over the past five years, the food supply has become <6 options>", N = 1014. Data source: HRA, 2007.

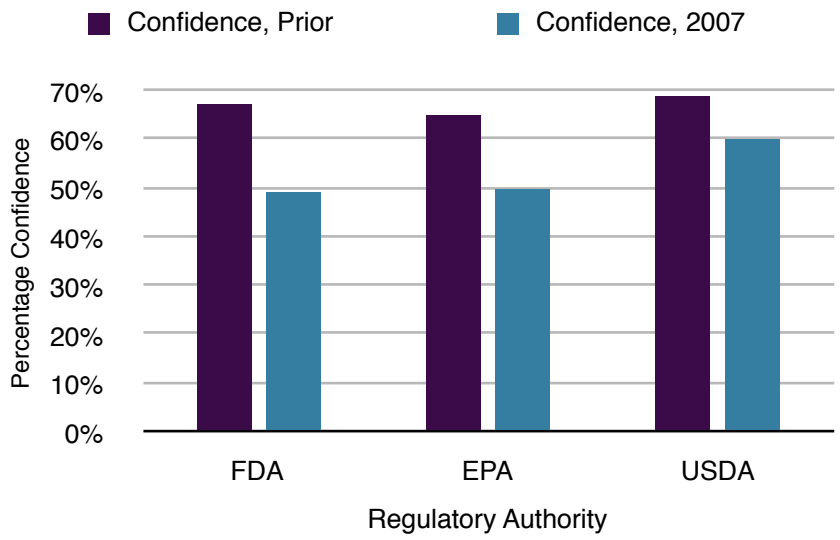


Figure 8. Public confidence decline in 3 US regulatory agencies: The US Food & Drug Administration, The US Environmental Protection Agency and the US Department of Agriculture. Percentage of respondents "approval ratings", reporting "The <Agency> does excellent/pretty good job", N = 1014 for 2007; Prior = 2001 for FDA & EPA; Prior = 2005 for USDA, earlier years for USDA not available; N for 2001 & 2005 not specified. Data source: HRA, 2007.

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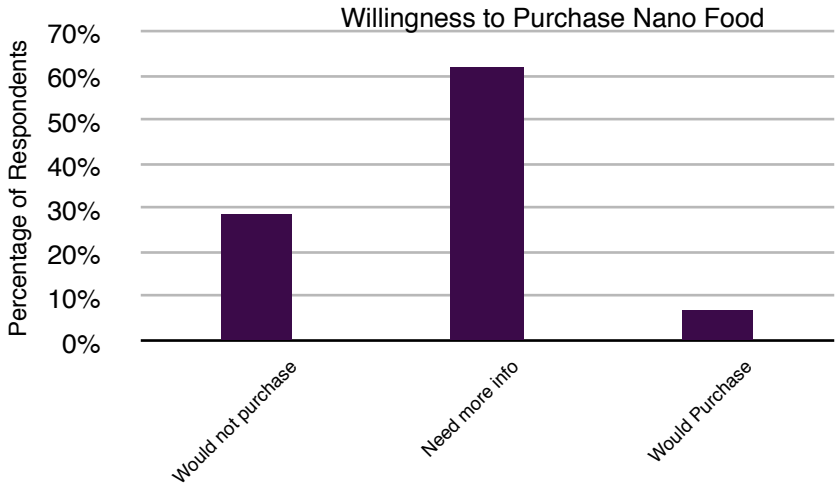

Figure 9. Percentage of respondents: "I would purchase food enhanced with nanotechnology"; "I would NOT purchase food enhanced with nanotechnology" or "I need more information about health risks and benefits to purchase food enhanced with nanotechnology", N = 1014. Data source: HRA, 2007.

Nanotechnology and Australia

According to a recent survey "covering 1000 randomly selected households" (MARS, 2007, p. 1) approximately one third of Australians surveyed could nominate a definition of nanotechnology, one third could not, and one third were unaware of the term nanotechnology (p.14). Most respondents (83%) were reported as "excited" or "hopeful" about the potential of nanotechnology, and 14% were "concerned" or "alarmed" (p. 21). Only 5% of respondents "know in detail what nanotechnology means and how it works", whereas "most have a limited understanding of what it means or how it works" (p. 3).

According to *Invest Australia* (2005, p.3) the "Australian Government is committed to developing a globally-focussed nanotechnology capability". The expenditure on research and commercialisation of nanotechnology is reported as A$100 million per year, and there are "over 50 nano-focussed companies commercialising Australia's research output" (p.3). *Invest Australia* report that the Australian Research Council (ARC) is "currently funding more than 200 nanotechnology-related projects, with a total of 322 projects receiving A$122 million since 1998" (p. 3), and that the Queensland Government "is establishing the A$60 million Australian Institute for Bioengineering and Nanotechnology (AIBN)" (p. 3).

Invest Australia (2005) report that the Australian nanoproduct *MesoLite*, from local company NanoChem Pty. Ltd., can remove ammonia from waste water, and that "Ammonia extracted through the MesoLite process, as well as used MesoLite materials themselves can be re-used as fertilisers" and that "MesoLite is in full-scale production" (p. 4).

The Australian product *Invisible Zinc* is advertised as "natural sun protection" which uses "Zinc Oxide ground down to nano-sized (one billionth of a metre) particle [sic]" (Ganehill, nd). On the occasion of the product being introduced into the US market, it was described as having been launched in Australia in 2004, and that it "has become the top-selling cosmetic in David Jones department stores" (Danks, 2008, p. 22).

Despite describing nanotechnology as a "frontier technology" (DEST, 2003, p. 295), the stated aim of the Australian government for this new technology, is: "to ensure a rapid transfer from science to product" (p. 295), including "for use in food production" and agriculture (p. 294). Australian community attitudes to nanotechnology are more cautious, with 65% of those surveyed, concerned about "unknown and long-term side effects", and 71% agreeing that it is important to know if products "are made with nanotechnology" (MARS, 2007, p. 22; Fig. 10).

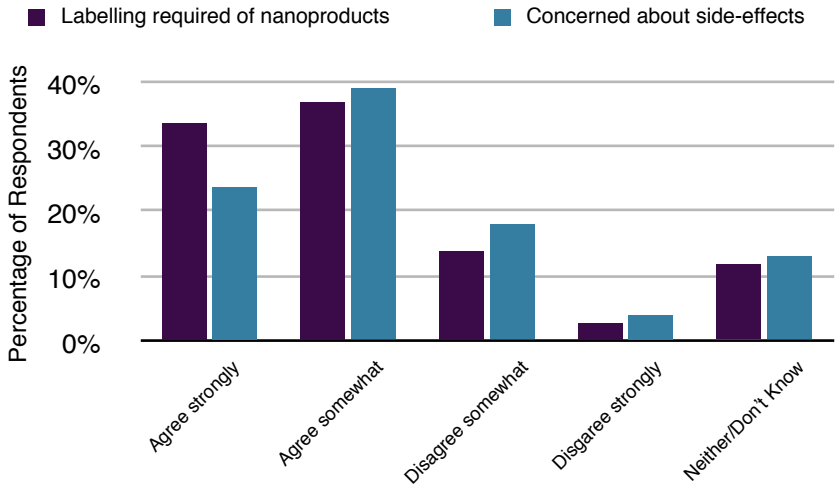

Figure 10. Responses to the questions: "It will be important for me to know if the products I buy are made with nanotechnology" and "I am concerned about the long-term side effects of nanotechnology", N = 1000. Data source: MARS, 2007.

According to Invest Australia (2007, p. 4), "Australian nanotechnology research is focused on identifying commercial opportunities". Their "Capability Report" identifies opportunities and capabilities including: biocides (p. 30); "food additives based on nanoscience that improve taste and physical attributes of foods and maintain food quality during transport and handling" (p. 37); and "nanocomposite material" for food packaging (p. 50), as well as "agriculture and food" (p. 36, p. 80). Food is mentioned 31 times in this report, agriculture 10 times, and the terms pesticide/s, herbicide/s and biocide/s together rate six mentions.

The interests of the *Australian Nuclear Science and Technology Organisation* (ANSTO) include researching "particulates for controlled release of active molecules in food, chemical, biocide, pesticide, pharmaceutical and cosmetic applications" (Mar & Harders, 2004).

The Australian company Plantic Technologies Ltd. trades using the motto: "Changing the nature of plastics", and promotes its products as "environmentally friendly plastics" (Plantic, 2007). Plantic asserts its environmental credentials, marketing "starch-based biodegradable" and "environmentally friendly plastics" derived from "corn starch" as film and packaging suited for food (Plantic, 2007). They claim to supply Cadbury Schweppes, Carrefour and Nestle. Yet the products are "nano-composite materials", comprising, for example, according to their US patent only "20% to 60% of a mixture of starch and/or a modified starch" (Halley *et al*., 2006). Such polymer nanocomposites are described as a "new class of material, nanosized inorganic filler … are dispersed in polymer matrix" (Nanocompositech, 2005); the environmental and ecological fates of such nanomaterials are unknown.

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Nanotechnology and Organics

The development and implementation of nanotechnology is proceeding in the near absence of health and safety considerations - including testing, monitoring and environmental-fate studies. This grand leap into the unknown is calculated to deliver profits for the few, at what may be profound and unmeasurable costs to the many. What is an appropriate response for the organic movement?

Try as one might, one cannot exclude the adventitious intrusion of pesticides, GMOs or even radiation into a food supply sourced from planet Earth. Wherever we are, and whatever are our food sources, we are all ingesting twentieth-century techno-pollution. In some cases, those furthest from the point of release can be the most affected. For example, "*certain Arctic indigenous populations, whose life style is based on the consumption of traditional country foods, are subject to some of the highest exposure levels to PTS [persistent toxic chemicals] of any population groups on Earth*" (AMAP, 2004, p. 8). As "*nanotechnology is likely to become ubiquitous throughout the world in short order"* (Thomas, 2007, p. 13), so in the wake of this can we expect the new ubiquity of nano-pollution? As with other crypto-pollution, organic standards can potentially exclude intentional and incidental nano-pollution (Table 1).

The organic community has adopted four guiding principles, the CHEF principles: Care, Health, Ecology and Fairness (IFOAM, 2005). As with other challenges, such as radiation and GMOs, the organic community has the opportunity to engage the Precautionary Principle or the Postcautionary Principle (Paull, 2007). Organic food is the world's gold standard in food purity assurance. As with other previous challenges, the response can be to exclude the offending items from the process of organic food production.

Governmental oversight will take time, may never be congruent with organic customer expectations, and labelling regulations may never eventuate. So it would seem incumbent on the organic community to take the initiative, and declare nano-ingredients as excluded inputs. The organic sector is in a better position than other food sectors to implement such an exclusion. This is because organic production (a) already champions low farm inputs, (b) already has an auditing system in place, (c) already has traceability protocols in place for all inputs, including farm inputs and processing inputs, as well as packaging and (d) already has a consumer-trusted certification and labelling system.

The UK's leading organic certifier, the Soil Association, has claimed a first in taking the initiative to exclude nanotechnology from January 2008. The "Soil Association Standards Board has banned manufactured nanoparticles as ingredients under our organic standards" (Soil Association, 2008). They state that they are adopting "a precautionary approach" and that "there is little scientific understanding about how these substances affect living organisms, indeed initial studies show negative effects". This is the first organic certifier to adopt such a stance.

Conclusions

Nanotechnology is being driven, worldwide, by commercial considerations; there is no consumer-driven pull for nanotechnology. The product applications and implications are proceeding amidst a deficiency of regulation, labelling requirements, safety and toxicity testing - and this is the situation worldwide. There is no consumer right-to-know whether they are ingesting, inhaling, wearing, or using, engineered nanoscale materials. Although nanoparticles have been incorporated into a wide variety of consumer products over the past several years, their environmental fate is unknown, their potential for bio-

accumulation is untested, and the long-term consequences are unknowable at this seminal stage of nanotechnology science. In the absence of nano-labelling consumers are thus unable to vote with their dollars, or to make informed choices and assessments of exposure.

Organic producers are at risk of introducing nanoparticles into the organic food stream by inadvertently or purposefully using chemicals, fabrics, packaging, paint and surface protectants, and/or filtration products, that incorporate engineered nanoscale materials. Use of such products risks migration of nanoparticles into organic food. The paths of transmission of nanomaterials into organic food includes, but is not limited to: on-farm chemical inputs; surface treatments including paint; filtration products including water treatment; food processing additives; clothing and textiles; and packaging including degradable and biodegradable plastics (Table 1).

Organic consumers cannot be assured of the safety of nanoscale materials in their food. To not proactively exclude such material from the organic food stream is surely a breach of the social contract between the organic sector and their customers, a social contract which is to provide what one prominent retailer promotes as food "grown as nature intended with no chemicals or additives, altogether a better way to eat" (Aldi, 2007, p. 11). The profit-driven introduction of nanomaterials into the food chain may be viewed, in retrospect, as a reckless or a benign adventure - in any event, this is a technology that cannot be detected by the purchaser, who must, as a consequence, rely on the fidelity of the food chain and labelling. The organic sector is uniquely well placed to put an exclusion in place, and to invoke the *stare decisis* principle with the prior response to GMOs serving as a precedent.

Nanotechnology is currently not addressed in any Organic Standard, other than that of the Soil Association (2008). This can be remedied, and ideally by the International Federation of Organic Agriculture Movements (IFOAM), but failing that, at the national level, or even failing that, at the certifier level. The exclusion of nano-inputs and nano-contamination does add to the regulatory burden, as well as the vigilance burden, for the organic sector. Because manufacturers of production and packaging inputs are not currently required to declare the nano-status of their supplies, a nano-exclusion adds an extra dimension to the maintenance of organic production integrity. The public seeking to exercise an option to ingest or not, and a right to know, are currently being thwarted by corporate and government interests. The only thoroughgoing reassurance to the organic purchasing public would be an unequivocal exclusion of nanoparticles and nano-technology from the organic food chain.

The Sufi poet Shabistari (1317, p. 79) reminds us that:

> *"If there were no sweepers in the world,*
> *the world would be covered in dust*".

If nanotechnology is the new dust, where are the new sweepers?

As nanotechnology ushers in the brave new world of so-called "advanced agriculture" (NNCO, 2006, p. 1), and colonises the food chain with "advanced food", this may create a flight from such techno-artefactual food, to organics. If this is the case, the organic community can draw benefit from taking a clear, unambiguous, and universal stance against nanofood - so that there is a haven for consumers who opt to be nano-refugees or nanofood abstainers. Nanotechnology, as a challenge to the integrity of organics, can thus be turned into an opportunity, by offering consumers a nano-free food choice. Agriculture is currently being identified and targeted by governments as a new playground for nanotechnology (NNCO, 2006; Invest Australia, 2007) and as a

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consequence, the organic sector does not have the luxury of a “no response” option. As consumers become increasingly disenchanted with the ability or willingness of arms of government to secure, what consumers consider to be a safe food supply (Figs. 7 & 8), the organic sector has an opportunity to take a vanguard position on this food safety, security, and right-to-know issue.

The organic sector has taken on the role of securing and maintaining the integrity of our food supply; nanotechnology is but the latest, and will surely not be the last, challenge to that integrity. The ETC Group (2005, p. 16) has called for “a moratorium on nanotech research and new commercial products … until these materials are shown to be safe”. Friends of the Earth (Miller & Senjen, 2008, p. 3) have called for a “moratorium on the further commercial release of food products, food packaging, food contact materials and agrochemicals that contain manufactured nanomaterials until nanotechnology-specific safety laws are established and the public is involved in the decision making”. The Organic Consumers Association (OCA, 2006, p. 7) has likewise called for “a moratorium on nanoparticles in consumer products”, and for “a formal ban on nanoparticles in all food labelled as organic”.

The issue with nanotechnology is that here is a technology of the invisible, that is being driven by industrial economics rather than consumer sentiment or commonweal, and it is infiltrating the food chain in a climate of inadequate testing, labelling, regulation and predictability. The ramifications, be they long or short term, are unknown for consumers, the biosphere, and the environment. The *No to Nano* call is within the scope of the organic community to implement, and is there any reason why this ought not be treated as a matter of urgency?

References Cited

Alberts, B., Bray, D., Lewis J., Raff, M., Roberts, K. & Watson, J., 1989, *Molecular Biology of the Cell, Second Edition*, Garland Publishing, New York.

Aldi, 2007, *Weekly News*, Aldi Stores, Australia, 9 October.

AMAP, 2004, *Persistent Toxic Substances, Food Security and Indigenous Peoples of the Russian North*, United Nations Environment Programme, Arctic Monitoring and Assessment Programme, Oslo, Norway.

AON, 2007, *Australian Office of Nanotechnology*, Department of Industry, Tourism and Resources (DITR), Canberra, 6 August, available at <www.industry.gov.au>, accessed 25 September 2007.

Breggin, L. K. & Pendergrass, J., 2007, *Where does the Nano go? End-of-Life Regulation of Nanotechnologies*, Woodrow Wilson International Center for Scholars, Project on Emerging Technologies, Washington, DC, July.

Bowman, D. & Hodge, G., 2007, A small matter of regulation: An international review of nanotechnology regulation, *Colombia Science & Technology Law Review*, 8, 1-32.

CAB, 2004, *Captain Hook Awards 2004*, Coalition Against Nanopiracy, Ottawa, ON.

Carafano, J. & Gudgel, A., 2007, Nanotechnology and national security: Small changes, big impact, *Backgrounder*, #2071, available at <www.heritage.org>, accessed 22 September 2007.

Chaplin, M., 2008, *Water Structure and Science*, London South Bank University, London.

Collins, P., 2007, Nothing but a ray of light, *New Scientist*, 195 (2620), 68-69, September 8.

Cornwell, D. & Featherstone, D., 2004, IP issues in nanotechnology - a view from around the world, *NSTI Nanotech2004*, Boston, MA, 10 March.

Costantino, L., Gandolfi, F., Tosi, G., Rivasi., F., Vandelli., M. & Forni, F., 2005, Peptide-derivatized biodegradable nanoparticles able to cross the blood-brain barrier, *Journal of Controlled Release,* 108 (1), 84-96.

Danks, K., 2008, Elle, 44, replaces Gale, *The Advertiser*, Adelaide, SA, p. 22., 6 January.

DEFRA, 2007, *Charcterising the Potential Risks posed by Engineered Nanoparticles, A Second UK Government Report*, Department of Environment, Food and Rural Affairs, London, December.

DEST, 2003, *Mapping Australian Science and Innovation - Main Report*, Department of Department of Education, Science and Training (DEST), Canberra, ACT.

Drexler, K. E., 1986 (reprint 1996), *Engines of Creation - The Coming Era of Nanotechnology*, Fourth Estate, London.

Drexler, K. E., 1992, *Nanosystems: Molecular Machinery, Manufacturing and Computation*, Wiley InterScience, New York.

EPA, 2007, *Nanotechnology White Paper*, Science Policy Council, Nanotechnology Workgroup, US Environmental Protection Agency, Washington, February.

EPA, 2008a, *Nanoscale Materials Stewardship Program*, US Environmental Protection Agency, Washington, 28 January, available at <www.epa.gov>, accessed 7 April 2008.

EPA, 2008b, *TSCA Inventory Status of Nanoscale Substances - General Approach*, US Environmental Protection Agency, Washington, 23 January, available at <www.epa.gov>, accessed 7 April 2008.

EPO, 2008, *Result List: Approximately 959 results found in the Worldwide database for: Yang Mengjun as the applicant or inventor*, European Patent Office, Munich, available at <v3.espacenet.com>, accessed 7 April 2008.

ETC Group, 2004, *Down on the Farm: The impact of Nano-scale Technologies on Food and Agriculture*, Action Group on Erosion, Technology and Conservation. Ottawa, Canada, November.

ETC Group, 2005, *A Tiny Primer on Nano-scale technologies and the "Little Bang Theory"*, Action Group on Erosion, Technology and Conservation. Ottawa, Canada, June.

ETC Group, 2007, First round of Nano-Hazard Symbol contest ends, *News Release*, Action Group on Erosion, Technology and Conservation. Ottawa, Canada, 10 January.

Ganehill, nd, *Invisible Zinc - The Benefits*, Ganehill Ltd, South Perth, WA, available at <www.ganehill.com.au>, accessed 6 April 2008.

Halley, P., Mcglashan, S. & Gralton, J., 2006, Biodegradable polymer, Plantic Technologies Ltd, *United States Patent*, #7094817, Washington, 22 August.

Harvie, D. I., 2005, *Deadly Sunshine - The History and Fatal Legacy of Radium*, Tempus Publishing, Stroud, UK.

Heartney, M. & Carlton, J., 2007, City of Berkeley's ordinance regulating nanotechnology raises key issues, *Client Advisory*, Arnold & Porter LLP, Washington, DC, March.

Hebert, P., 2007, *Top Nations in Nanotech See Their Lead Erode*, Lux Research, New York, 8 March.

Herzig, R., 1999, Removing roots: North American Hiroshima maidens and the X-ray, *Technology and Culture*, 40(4), 723-745.

Hoet, P., Bruske-Hohlfeld, I. & Salata, O., 2004, Nanoparticles - known and unknown health risks, *Journal of Nanobiotechnology*, 2:12, 1-19, available at <www.nanobiotechnology.com>, accessed 22 September 2007.

HRA, 2007, *Awareness of and Attitudes Toward Nanotechnology and Federal Regulatory Agencies, A Report of Findings*, Peter D. Hart Research Associates Inc., Washington, 25 September.

Hsu, A., 2006, Taiwanese government launches nanoproduct certification system, *Taiwan Journal*, XXIII (6), 17 February, available at <www.taiwanjournal.nat.gov.tw>, accessed 8 April, 2008.

IFOAM, 2005, *The Principles of Organic Agriculture*, International Federation of Organic Agriculture Movements, Bonn, Germany.

Invest Australia, 2005, *Australian Nanotechnology Water and Environment*, Department of Communications, Information Technology and the Arts (DCITA), Canberra, ACT.

Invest Australia, 2007, *Nanotechnology Australian Capability Report, Third Edition*, Department of Communications, Information Technology and the Arts (DCITA), Canberra, ACT.

Ludlow, K., 2007, One size fits all? Australian regulation of nanoparticle exposure in the work place, *Journal of Law and Medicine*, 15 (1), 136 - 152.

Mar, L. & Harders, J., 2004, *Australian Directory of Nanotechnology Service Providers - 2004*, The Warren Centre for Advanced Engineering, The University of Sydney, Sydney, NSW.

Marburger, J. (ed.), 2007, *Supplement to the President's 2008 Budget*, The National Nanotechnology Initiative, National Science and Technology Council, Washington, July.

 ISSN 1177-4258

MARS, 2007, *Final Report: Australian Community Attitudes Held About Nanotechnology - Trends 2005 - 2007*, Market Attitude Research Services, Miranda, NSW, Australia, report prepared for Department of Industry, Tourism and Resources (DITR), Canberra, ACT, 12 June.

Maynard, A., Aitkin, R., Butz, T., Colvin, V., Donaldson, K., *et alia*, 2006, Safe handling of Nanotechnology, *Nature*, 444, 267-269.

Mengjun, Y., 2002a, *Nano medicine 'Shengli' and its preparation*, European Patent Office Database, Munich, CN1368319, 11 September.

Mengjun, Y., 2002b, *Nano medicine 'Shuxinjangzhi' and its preparation*, European Patent Office Database, Munich, CN1368316, 11 September.

Miller, G. & Kinnear, S., 2007, Nanotechnology: A new wave of assaults on our food, C*leanFood Organic*, 4, 52-57.

Miller, G & Senjen, K., 2008, *Out of the Laboratory and on to our Plates*, Friends of the Earth, Australia, Europe & USA, March.

Monica, J., Heintz, M. & Lewis, P., 2007, The perils of pre-emptive regulation, *Nature Nanotechnology*, 2, 68-70.

NNCO, 2006, *Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials*, The National Nanotechnology Initiative, National Nanotechnology Coordination Office, Washington, September.

Northbourne, L., 1940, *Look to the Land*, J.M. Dent, London.

NRDC, 2005, *NRDC and others comment on EPA proposal to regulate nanomaterials through a voluntary program,* The Natural Resources Defense Council & eleven other NGOs, OPPT-2004-0122, June.

OCA, 2006, Tiny toxins - Shoppers guide to nanotechnology, *Organic View*, Organic Consumers Association, Finland, MN, 7, Autumn.available at <www.organicconsumers.org>, accessed 24 September 2007.

O'Connor, B., 2006, *Slim Shake Chocolate*, RBC Life Sciences, Irving, TX, available at <www.rbclifesciences.com>, accessed 18 September 2007.

Pacific Corp (KR), 2003, *Nanoemulsion comprising metabolites of ginseng saponin and a skin-care composition for ant-aging containing the same*, European Patent EP1327434, 16 July, available at <www.freepatentsonline.com>, accessed 6 April 2008.

Paull, J, 2007, Certified organic forests & timber: the Hippocratic opportunity, *Australia New Zealand Society for Ecological Economics Conference,* Noosa Heads, QLD, July 3 - 6, available at <orgprints.org/11042>, accessed 24 September 2007.

Plantic, 2007, *Trading Update*, Plantic Technologies Ltd., Altona, VIC, 3 July.

Roco, M. C., 2007a, National Nanotechnology Initiative - Past, Present, Future, in *Handbook of Nanoscience, Engineering and Technology, Second Edition*, W. Goddard, D. Brenner, S. Lyshevski & G. Iafrate (editors), CRC Press, Boca Raton, FL..

Roco, M. C., 2007b, National Nanotechnology Initiative - Past, Present, Future, in *Handbook of Nanoscience, Engineering and Technology*, 2nd ed., W. Goddard, D. Brenner, S. Lyshevski & G. Iafrate (editors), CRC Press, Boca Raton, FL, preprint.

RS & RAE, 2004, *Nanoscience and nanotechnologies: Opportunities and uncertainties*, The Royal Society & The Royal Academy of Engineering, London.

Regis, E., 1995, *Nano!*, Bantam Press, London.

Saito, R., Krauze, M., Bringas, J., Noble, C., McKnight, T., *et alia*, 2005, Gadolinium-loaded liposomes allow for real-time magnetic resonance imaging of convection-enhanced delivery in the primate brain, *Experimental Neurology,* 196 (2), 381-389.

Shabistari, M., 1317 (reprint 2002), *The Secret Rose Garden*, Phanes Press, Grand Rapids, MI.

Soil Association, 2008, Soil Association first organisation in the world to ban nanoparticles - potentially toxic beauty products that get right under your skin, *Press Release*, Soil Assocation, London, 17 January (version 4), available at <www.soilassociation.org>, accessed 6 April 2008.

Steiner, R., 1924 (reprint 2003), *Agriculture Course, the Birth of the Biodynamic Method, Eight Lectures and Discussions*, Skylark Books, Hastings, UK.

Thomas, J., 2007, Nanotechnology all around us: A wake-up call for the organic sector, *Ecology & Farming*, 40, 13-19, May - August.

Uldrich, J. & Newberry, D., 2003, *The Next Big Thing is Really Small - How Nanotechnology will Change the Future of your Business*, Crown Business, New York.

WWICS, 2007a, *A Nanotechnology Consumer Products Inventory*, Woodrow Wilson International Center for Scholars, Project on Emerging Technologies, available at <www.nanotechproject.org>, accessed and data set as at 24 September 2007.

WWICS, 2007b, *Americans Look to Government to Ensure Safety of New Technology*, Woodrow Wilson International Center for Scholars, Project on Emerging Technologies, 25 September, available at <www.nanotechproject.org>, accessed 11 October 2007.

WWICS, 2008, *Nanotechnology Project - Methodology*, Woodrow Wilson International Center for Scholars, Project on Emerging Technologies, available at <www.nanotechproject.org>, accessed 8 April 2008.

ISSN 1177-4258