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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 nanometers. At this size, materials exhibit novel behaviours. Nanotechnology is a rapidly expanding multibillion dollar industry, with research being heavily promoted by Western governments. 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 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 first 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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Organic Context

Organic agriculture was originally conceived as a response to artificial fertilisers, pesticides, and the industrialization of farming (Steiner, 1924; Northbourne, 1940). Since that time, the organic community has responded to the challenge of emergent technologies potentially usurping the integrity of the organic philosophy, two examples of which 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. 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 his more technically dense book: "Nanosystems: Molecular Machinery, Manufacturing and Computation" (1992). "Arranged one way, atoms make up soil, air and water, arranged another, they make up ripe strawberries", wrote Drexler (1986, p. 3). Drexler's ideas were, and remain, bold and innovative, and they attracted a certain amount of 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, using atoms as their building blocks - 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 could have been a science fiction writer. As it is, his vision has borne fruit, but very different from the picture 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 twenty years on, there are no Drexler self-replicating machines, and no nanobots to go out of control creating a "grey goo" world. And perhaps because of his optimism and the science fiction feel of Drexler, in the shadow of his perhaps fanciful vision, has grown a nanotechnology industry of very low public visibility, and no government oversight.

While there is "no globally recognized definition of nanotechnology" (Roco, 2007, p. 2), there are nevertheless many definitions. 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 (2007, p. 2,3) makes the point that a

definition needs to address three issues: “*the size range*”, “*the ability to measure and transform*” and “*exploiting properties and functions specific to the nanoscale as compared to the macro or micro scales; 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).

A Note on Terminology

Nanotechnology is a rapidly developing domain of research and practice, and 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 nanometre² is one billionth of a metre). Nanotechnology is developing both “nanoscale versions of existing materials, [and] entirely new classes of materials” (NNCO, 2006, p. 1).

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, 2007), but no regulation anywhere in the world (Bowman & Hodge, 2007).

Government expenditure on nanotechnology in 2006 is reported as totalling US\$4.681 (Roco, 2007, Fig. 1). The US President's 2008 budget request is for \$1.444 billion in government research funds for nanotechnology, with a stated goal of 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*

² 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.

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.

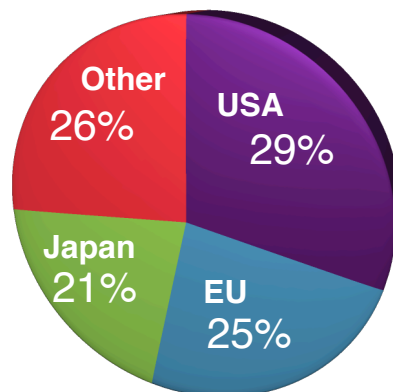


Figure 1. Distribution of US\$4.681 billion worldwide government R&D expenditure on Nanotechnology in 2006. USA: US\$1.351 billion,; EU US\$1.150 billion; Japan US\$980 billion, Other US \$1.200 billion. Data source: Roco, 2007.

The founder of the US *National Nanotechnology Initiative* (NNI), Roco (2007, 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 reports that "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" (p. 9). The initial strategy was one of "communicating the vision to large communities and organizations" (p. 11). "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. 14). Now, "Research is advancing toward systematic control of matter at the nanoscale faster than envisioned ... All major science and engineering colleges in United States have introduced courses related to nanoscale science and engineering" (p. 20). Roco reports triumphantly that "in January 2006 ... President Bush listed nanotechnology as a top technological opportunity for national competitiveness" (p. 32). An upcoming challenge is "Expanding to new areas of relevance", including "food and agriculture" (p. 33).

Nano-Products

In a recent inventory of consumer nanotechnology, 580 products have been identified, and classified into eight categories (WWICS, 2007a, Fig. 2). 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.

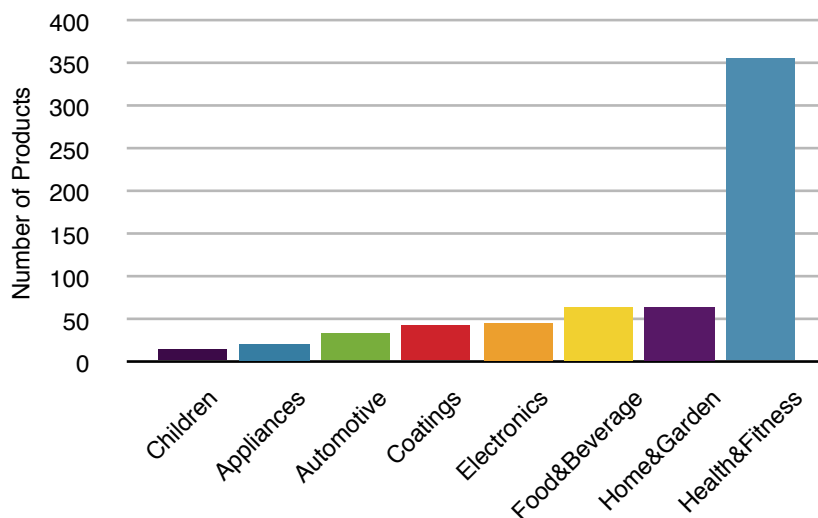


Figure 2. Products incorporating nanotechnology currently in the market, N = 580. Note: some products are attributed to more than one category. Data source: WWICS (2007a).

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 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 over the internet from a USA address.

Food and Beverage accounted for 11.4% (n = 66) of the total (WWICS, 2007a). These products were further classified 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, 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).

Major food and beverage corporations are investing in nanotechnology. The ETC Group (2004, p. 63) identify Nestle, Kraft, Unilever, PepsiCo, General Mills, Campbell Soup, McCain, Goodman Fielder, and others as among the companies involved. 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?

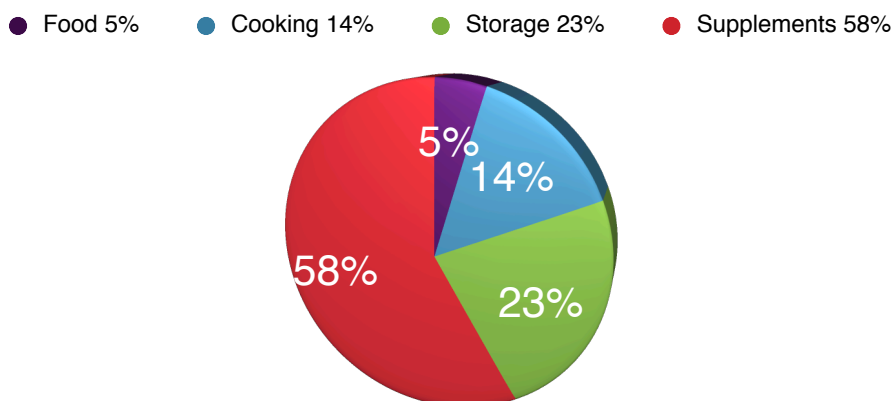


Figure 3. Distribution by sub-category of nanotechnology products classified as *Food and Beverage*, n = 66. Data source WWICS (2007a).

Nano-Uncertainties

Carafano & Gudgel (2007, p. 3) identify 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 legislative control (RS & RAE, 2004; Bowman & Hodge, 2007; Beggin & Pendergrass, 2007). “That there is no regulatory oversight is chilling”, according to Miller & Kinnear (2007, p. 56).

Emphasising the uncertainty of nono-safety, the US EPA Nanotechnology White Paper (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 - 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 the nano-contamination of food.

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).

Hoet, Bruske-Hohfeld & Salata (2004) identify that to argue either for, or against nanotechnology, “it is extremely hard to argue their case as there is limited information available to support one side or the other” (p. 1). They make the point that “human skin, intestinal tract and lungs are always in direct contact with the environment” and that they consequently present potential portals of access to nanoparticles of respectively 1.5m², 140 m² and 200 m²; thereby presenting relatively massive targets for nanoparticles of size 10⁻⁹ metres. 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 deposition in “the liver, spleen, blood and bone marrow” (p. 8); they report 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). Hoet *et al.* Conclude that “each nanomaterial should be treated individually” for the purposes of health risk assessment, they call for “a database of health risks associated with different nanoparticles” and they declare that “Nanoparticles designed ... as food components need special attention” (p. 10).

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 merely being formulated, they are far from being answered. It is declared that nanotechnology “will likely be the foundation for achieving widespread benefits, including ... advanced agriculture” (NNCO, 2006, p. 1); although what those benefits might be, to whom the benefits might accrue, at what cost and to whom, and just

what this *de novo* “advanced agriculture” might be, remain unanswered questions. Is nanotechnology the new sliced bread, the new snake oil, or a new Pandora’s box? - we are all without the data, and/or the tools, to make such a determination, or even a guesstimate, and while 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 any such principle.

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).



Figure 4. Example of a proposed Nano-Hazard symbol; 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); and there remains the outstanding requirement, familiar to other toxic and potentially toxic technologies, to : “determine the best methods for waste disposal” (p. 50).

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 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 nonoparticles can be anticipated to be a function of whether they are free or bound (or embedded), as well as how, where, and when the transitions between the free and bound states may occur.

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

Nanotechnology & 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 survey, 71% of respondents professed to know little or nothing of nanotechnology (Fig. 5), and 51% of respondents indicated uncertainty over the risks *versus* benefits (Fig. 6; HRA, 2007). At the same time, 61% of respondents declared their perception, that food in general was less safe than five years ago (Fig. 7); and 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, while 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.

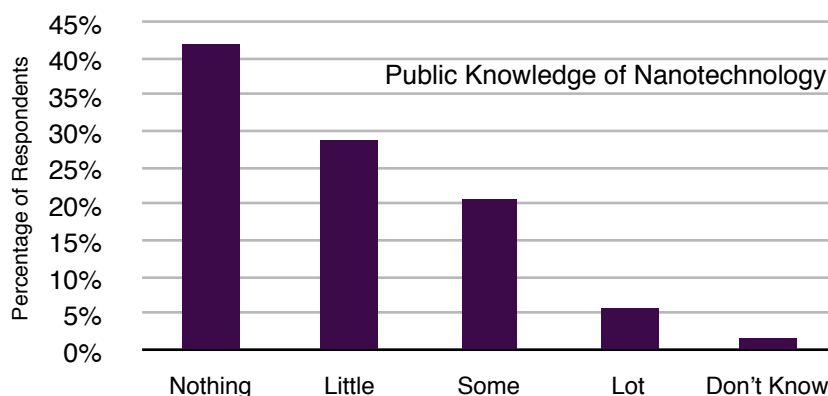


Figure 5. Public awareness of nanotechnology, Respondents were asked “Have you heard much about nanotechnology?”, N = 1 014. Data source: HRA, 2007.

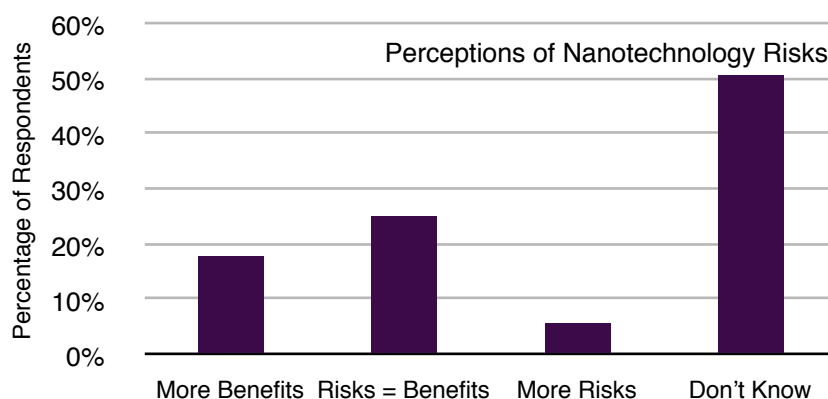


Figure 6. Respondent's “Initial impression of risks and benefits of nanotechnology”, N = 1014. Data source: HRA, 2007.

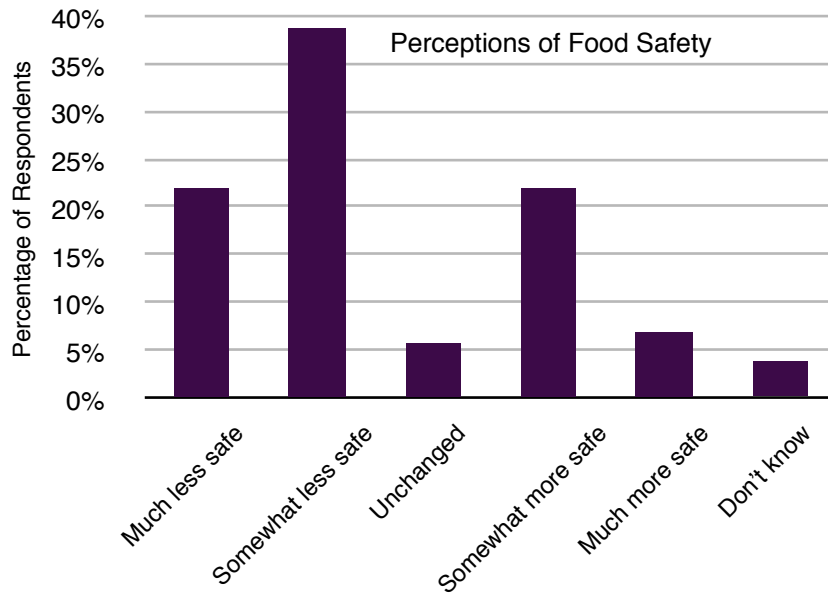


Figure 7. Percentage of respondents completing the sentence: “Over the past five years, the food supply has become <6 options>”, N = 1014. Data source: HRA, 2007.

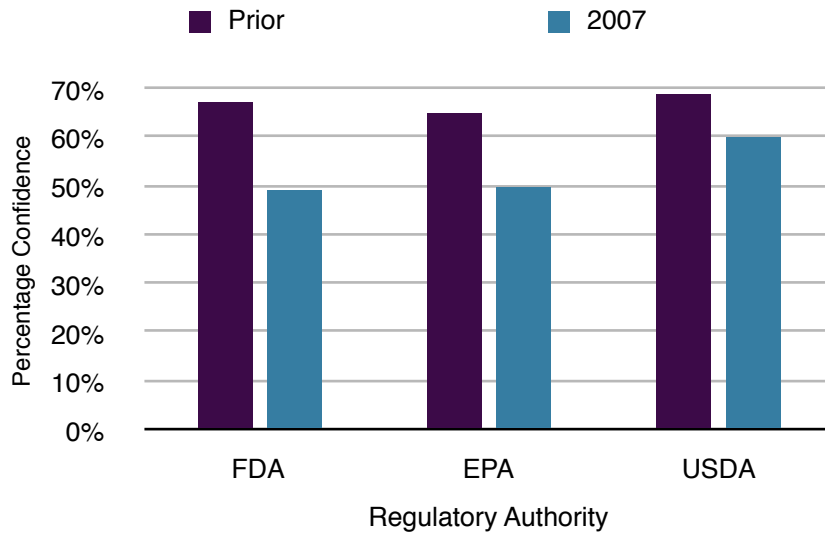


Figure 8. Public confidence decline in 3 US regulatory agencies: The US Food & Drug Administration, The US Environmental Protection Agency and the US Department of Agriculture. Percentage of respondents “approval ratings”, reporting “The <Agency> does excellent/pretty good job”, N = 1014 for 2007; Prior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

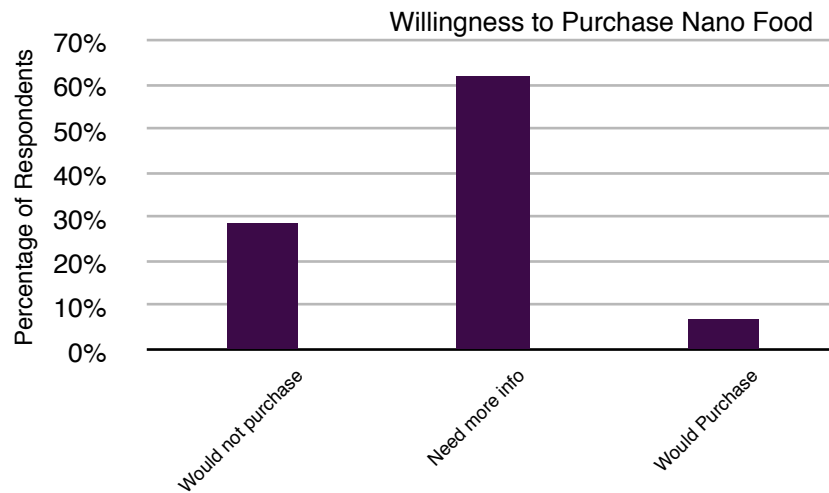


Figure 9. Percentage of respondents: “I would purchase food enhanced with nanotechnology”; “I would NOT purchase food enhanced with nanotechnology” or “I need more information about health risks and benefits to purchase food enhanced with nanotechnology”, N = 1014. Data source: HRA, 2007.

Nanotechnology & Australia

According to a recent survey, around one third of Australians surveyed could nominate a definition of nanotechnology, one third could not, and one third were not aware of the term nanotechnology (MARS, 2007, p.14). Reportedly, 83% of respondents were “excited” or “hopeful” about the potential of nanotechnology, while 14% were “concerned” or “alarmed” (p. 21); they record that 5% of respondents “know in detail what nanotechnology means and how it works”, while “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). 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). The Queensland Government “is establishing the A\$60 million Australian Institute for Bioengineering and Nanotechnology (AIBN)” (p. 3).

Invest Australia report that an Australian nanoproduct MesoLite, from local company NanoChem Pty. Ltd., can remove ammonia from waste water, 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).

Despite describing nanotechnology as a “frontier technology” (DEST, 2003, p. 295), there is the stated Australian government aim of: “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% 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).

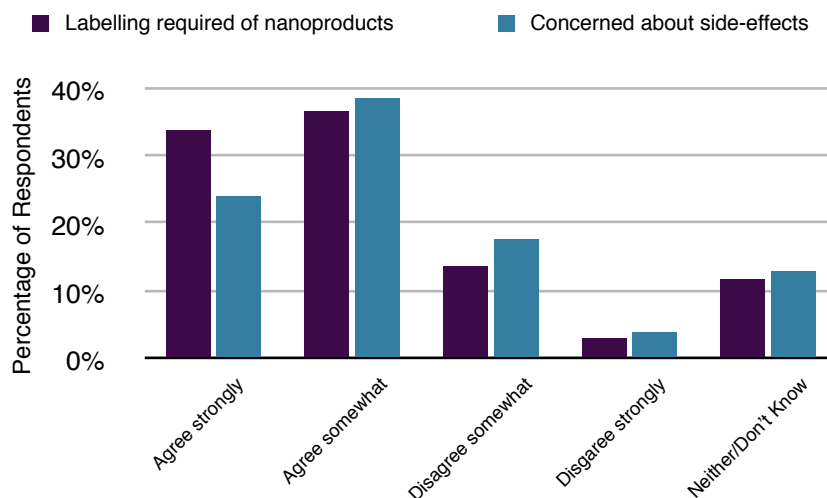


Figure 10. Responses to the questions: "It will be important for me to know if the products I buy are made with nanotechnology" and "I am concerned about the long-term side effects of nanotechnology", N = 1000. Data source: MARS, 2007.

"Australian nanotechnology research is focused on identifying commercial opportunities" according to Invest Australia (2007, p. 4). 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, while pesticides, herbicides and biocides rate 6 mentions.

The *Australian Nuclear Science and Technology Organisation* (ANSTO) is 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 promotes 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" (Nanocompositetech, 2005); the environmental and ecological fates of such nanomaterials are unknown.

Nanotechnology & 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. Nanotechnology is a grand leap into the unknown, 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 - we are all ingesting twentieth-century techno-pollution - wherever we are, and whatever are our food sources. Those furthest from the point of release can be the most effected - 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 will be likely 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 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 arrive at all. 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 to implement such an exclusion than other food sectors because (a) organic production already champions low farm inputs and (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.

Conclusions

Nanotechnology is being driven, worldwide, by commercial considerations; there is no consumer-driven push for nanotechnology. The product applications and implications are proceeding in the absence of regulation, labelling requirements, safety and toxicity testing - and this is the situation worldwide. There is no consumer right-to-know that they are ingesting, inhaling, wearing, or using, engineered nanoscale materials. Although nanoparticles have been incorporated into a wide variety of consumer materials over the past several years, their environmental fate is unknown, their potential for bioaccumulation 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, or 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 material. 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, 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 at some point in the future 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. This can be remedied, ideally at the IFOAM level, and failing that, at national, 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. Since manufacturers of production and packaging inputs are not 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 nanotechnology 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. That being 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 being identified and targeted by governments as a new playground for nanotechnology (NNCO, 2006; Invest Australia, 2007), and as a 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 see as, 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”. 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”. Nanotechnology is invisible, untested, unlabelled and unpredictable - 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?

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