TINY INGREDIENTS BIG RISKS

NANOMATERIALS RAPIDLY ENTERING FOOD AND FARMING

Friends of the Earth

ACKNOWLEDGEMENTS

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About Friends of the Earth

Friends of the Earth-U.S., founded by David Brower in 1969, is the U.S. voice of the world's largest federation of grassroots environmental groups, with a presence in 74 countries. Friends of the Earth works to defend the environment and champion a more healthy and just world. Through our 45-year history, we have provided crucial leadership in campaigns resulting in landmark environmental laws, precedent-setting legal victories and groundbreaking reforms of domestic and international regulatory, corporate and financial institution policies. **www.foe.org**

Any errors or omissions in this report are the responsibility of Friends of the Earth.

This report has been edited to reflect new information as of June 13, 2014. Companies who have recently claimed they do not introduce nanoscale titanium dioxide into products highlighted on our nanofoods list have been removed. Friends of the Earth removed 11 products from our nanofoods product list to reflect claims made by companies regarding their use of nanomaterials. We have also added an additional 2 recently confirmed nanofood products to our list.

We encourage companies to inquire with their suppliers about the use of nanomaterials (beyond just titanium dioxide) in all products they offer. Lack of labeling laws and regulation in this area make it very difficult to assess the presence of these potentially hazardous ingredients in food, beverages and other products. Please note that Friends of the Earth has not conducted tests on products and cannot guarantee the nanomaterial content of brands on our nanofoods product list. For the purpose of this report we use the term "nano" to include particles up to 1,000 nm in size, due to the evidence of nano-specific problems associated with particles up to this size range.

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EXECUTIVE SUMMARY

This new analysis by Friends of the Earth documents a 10-fold increase in unregulated, unlabeled "nanofood" products on the American market over the past six years. A growing body of science suggests that these materials pose risks to the health of consumers, workers and the environment.

Nanomaterials are produced by way of nanotechnology and are now found in a broad range of products.

Nanotechnology has been provisionally defined as relating to materials, systems and processes, which exist or operate at a scale of 100 nanometers (nm) or less. However, this definition is still in flux, and some U.S. and EU regulators define nanomaterials as being in a size range of less than 1,000 nm across for drugs and other purposes.

Nanotechnology involves the manipulation of materials and the creation of structures and systems at the scale of atoms and molecules, the nanoscale. The properties and effects of nanoscale particles and materials differ significantly from larger particles of the same chemical composition. According to the Woodrow Wilson International Center for Scholars, foods containing nanomaterials are rapidly entering the market at a rate of three to four per week.

> The number of nanofood and beverage products we know to be on the market has grown to 87—a more than tenfold increase in six years.

In 2008, Friends of the Earth released a groundbreaking report on the use of nanomaterials in food and agriculture, "Out of the laboratory and onto our plates: Nanotechnology in food and agriculture." Six years later, the U.S. Government has made little progress in protecting the public from these potentially dangerous food ingredients, despite the fact that the number of nanofoods on the market is expanding rapidly.

Key findings of this report include:

- **Nanomaterials are found in a broad array of common foods.**
  Many food items that Americans eat on a daily basis contain nanomaterial ingredients. These include familiar products such as processed and cream cheeses, cookies, doughnuts, coffee creamer, chocolate syrup and other chocolate products, pudding, mayonnaise, mashed potatoes, milk, soy, almond, and rice beverages, mints, gum, popcorn, salad dressing and oils, yogurt, cereal, candy, crackers, pasta and sports drinks. There is also mounting evidence that nanomaterials are being used to package and preserve fresh fruit and vegetable products, which could threaten the integrity of staple healthy foods.

- **The amount of nanofood we know to be on the market has grown more than tenfold in six years.**
  In 2008 we found 8 food and beverage products with nano-ingredients on the market. In 2014, the number of nanofood and beverage products we know to be on the market has grown to 87—a more than tenfold increase in six years. This analysis is based on information documented in the Woodrow Wilson International Center for Scholars' Project on Emerging Technologies Consumer Products Database, however, the rapid growth in nanofood products on the market has yet to be

analyzed or reported on in mainstream media. These products are being made by major companies including Kraft, General Mills, Hershey, Nestle, Mars, Unilever, Smucker's and Albertsons. Due to a lack of required labeling and disclosure, the number of food and beverage products containing undisclosed nanomaterials is likely much greater.

- **Major food companies are investing billions in nanofood and nanopackaging.**
  Roughly 200 transnational food companies are currently investing in nanotech and are on their way to commercializing products. The nanofoods market is expected to grow to US$20.4 billion by 2020.

- **An increasingly large body of peer-reviewed evidence indicates some nanomaterials may harm human health and the environment.**
  Nanomaterials have unique properties that offer many new opportunities for food industry applications, such as potent nutritional additives, stronger flavorings and colorings, or antibacterial ingredients for food packaging. However, these same properties may also result in greater toxicity for humans and the environment. Nanoparticles pose new risks because:

  – They can be more chemically reactive and more bioactive than larger particles of the same chemicals.

  – Due to their very small size, nanoparticles also have much greater access to our bodies, so they are more likely than larger particles to enter cells, tissues and organs.

  – Greater bioavailability and greater bioactivity may introduce new toxicity risks.

  – They can compromise our immune system response.

  – They may have long-term pathological effects.

Nanoparticles of silver, titanium dioxide, zinc and zinc oxide, materials now used in nutritional supplements, food packaging and food contact materials, have been found to be highly toxic to cells in test tube and animal studies. Preliminary environmental studies also suggest that these substances may be toxic to ecologically significant species such as certain crustaceans, which are an important part of the food chain. Yet there is still no nanotechnology-specific regulation or safety testing required before manufactured nanomaterials can be used in food, food packaging, or agricultural products. Health experts have also raised concerns that the widespread use of nanosilver in consumer products will further increase the problem of antibiotic-resistant superbugs.

Nano titanium dioxide (Ti02)

Most of the nanomaterial food products Friends of the Earth identifies in this report contain nano titanium dioxide. In laboratory studies, nanoparticles of titanium dioxide have been found to be immunologically active, meaning they cause a reaction from the body's defensive system. Recent studies have indicated these particles may play an important role in the initiation or exacerbation of gastrointestinal inflammation, by adsorbing bacterial fragments and then carrying them across the gastro-intestinal tract.

Nano-silver

In the Woodrow Wilson inventory of nano products, silver is the most common nanomaterial mentioned in product descriptions. A recent court case in the United States found that the use of nano-silver was 'ubiquitous' and that there was no way for consumers to avoid exposure. Food and food contact products identified as containing nano-silver include baby bottles, food containers, packaging, cutting boards, salad bowls, appliances, cutlery, ice trays, filtration devices and collapsible coolers. In agriculture it is used in poultry production and agricultural and aquacultural disinfectants.

There is mounting evidence that nanosilver may have greater toxic effects when compared with bulk silver. Nano-silver can better penetrate biological barriers and attach itself to the outside of cells. Nanoscale silver can also enter the bloodstream and reach all organs of the body, including the brain, heart, liver, kidneys, spleen, bone marrow and nervous tissue. Animal studies have shown placental transfer and fetal uptake of nano-silver, a finding made disturbing by a recent study that found exposure to nano-silver caused zebra fish embryos to develop with head abnormalities and no eyes. Zebra fish have been widely used as a model organism for the study of embryological development in other vertebrates including humans.

Health experts have also raised concerns that the widespread use of nano-silver in consumer products will further increase the problem of antibiotic-resistant superbugs.

- **Nanomaterials raise concerns for the health of workers**

  In the food sector, workers may come into contact with nanomaterials during production, packaging, transport, distribution and waste disposal of food and agrochemicals. To date, there is very little data relating to the exposure of workers to nanomaterials. Studies have shown that nanomaterials can enter the bloodstream via the lungs, raising major occupational health and safety concerns.

- **Nanotechnology also poses broader challenges to the development of more sustainable food and farming systems**

  Against the backdrop of climate change, there is growing public interest in reducing the distances that food travels between producers and consumers. Nanotechnology appears likely to promote transport of fresh and processed foods over even greater distances. It has the potential to further concentrate corporate control of global agriculture and food systems and entrench systems of reliance on chemical and energy-intensive agriculture technologies. The erosion of local farmers' control of food production is also a source of concern.

- **Nano-agrochemicals are now being used on farms and released into the environment in the absence of regulations**

  Conventional agrochemicals have polluted soils and waterways and have caused substantial disruption to ecosystems. Exposure to agrochemicals has also been linked with greater incidence of cancer and serious reproductive problems among agricultural workers and their families. Consequently, it is of great concern that nano-agrochemicals are now being used on farms and released into the environment, absent regulations that require product manufacturers to demonstrate the safety of new, more potent nanoscale formulations of existing chemicals.

- **U.S. regulation of nanomaterials is wholly inadequate and leaves consumers, workers and the environment at risk**

  A growing number of civil society organizations worldwide have called for precautionary management of nanotechnology, culminating in the release of "Principles for the Oversight of Nanotechnologies and Nanomaterials." More than 70 groups from six continents have endorsed that document.

While the U.S. FDA is charged with ensuring "the safety and security of our nation's food supply," at this time the agency has merely offered nonbinding guidance to industry on the use of nanomaterials in food. However, the agency's 2012 draft guidance on the use of nanomaterials in food warns about the different properties of nanomaterials compared to ingredients used in traditional manufactured food substances. Nevertheless, the lack of established regulations allows nanofood products to remain on the market while the public takes up potential health risks.

> The extent to which nanomaterials are used along the food chain continues to be shrouded with mystery.

The U.S. Environmental Protection Agency has legal powers to compel nano agrochemicals manufacturers to provide toxicity data and to demonstrate product safety — that is, to place the burden of proof on the manufacturers. Producers of pesticide products must submit scientific and technical data for EPA review. However, according to a U.S. General Accountability Office report, "EPA estimated that companies provided information on only about 10 percent of the nanomaterials that are likely to be commercially available. EPA also reported that in its review of data submitted through its data collection program there were instances in which the details of the manufacturing, processing, and use of the nanomaterials, as well as exposure and toxicity data, were not provided."

Moreover, the extent to which nanomaterials are used along the food chain continues to be shrouded with mystery due to the lack of publicly accessible product registries or product labels made mandatory by our regulators, leaving consumers, workers, other companies along the supply chain and even regulators in the dark.

Recommendations:

Given the potentially serious health and environmental risks and social implications associated with nanofoods, Friends of the Earth is calling 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 and labeling laws are established and the public is involved in decision-making.

What government must do:

Nanomaterials must be regulated as new substances.

- All manufactured nanomaterials must be subject to safety assessments as new substances, even where the properties of their larger scale counterparts are well known.
- All deliberately manufactured nanomaterials must be subject to rigorous nano-specific health and environmental impact assessment and demonstrated to be safe prior to approval for commercial use in foods, food packaging, food contact materials or agricultural applications.
- Assessments must be based on the precautionary principle and the onus must be on manufacturers to comprehensively demonstrate the safety of their product. No data, no market.
- Safety assessment must be based on the nano content of products, not marketing claims.
- Safety assessment must include the product's entire life cycle.

The size-based definition of nanomaterials must be extended.

- All particles up to 1,000 nm in size must be considered to be "nanomaterials" for the purposes of health and environment assessment, given the early evidence that they may pose health risks similar to particles less than 100 nm in size which have to date been defined as "nano."

Transparency in safety assessment and product labeling is essential.

- All relevant data related to safety assessments, and the methodologies used to obtain them, must be placed in the public domain.
- All manufactured nano-ingredients must be clearly indicated on product labels to allow members of the public to make an informed choice about product use.
- The presence of nanomaterials must be disclosed to workers and other downstream users along the supply chain.

Public involvement in decision-making is required.

- The public, including all affected stakeholder groups, must be involved in all aspects of decision making regarding nanotechnology in food and agriculture. This includes in the development of regulatory regimes, labeling systems, and prioritization of public funding for food and agricultural research. People's right to avoid nanofoods must be recognized explicitly.

Support for sustainable food and farming is needed.

- The assessment of food and agricultural nanotechnology, in the context of wider societal needs for sustainable food and farming, must be incorporated into relevant decision making processes.

What industry must do:

Food producers and retailers must respect people's right to healthy foods, in which all ingredients have been proven safe. Food producers and retailers must stop selling nanofood, nanofood packaging, nanofood contact materials and nano-agrochemicals until:

- The public is involved in decision making.
- Nanotechnology-specific regulation is put in place to protect the public, workers and the environment from potential new hazards associated with nano-toxicity.
- All manufactured nano-ingredients are clearly indicated on product labels, allowing members of the public to make an informed choice about product use.
- The presence of nanomaterials is disclosed to workers and other downstream users along the supply chain.
- Manufacturers work with regulators to ensure that their products have undergone appropriate safety testing, and provide the relevant data regarding the health and environmental safety of their product. No data, no market.
- All relevant data related to safety assessments, and the methodologies used to obtain them, are placed in the public domain.
- All food and agricultural products which include manufactured nanomaterials are clearly labeled to allow members of the public, workers and farmers to make an informed choice.

What concerned individuals and organizations can do:

Until we can move our government and companies to manage nanotechnology in a responsible and transparent manner, there are steps we can take to protect our health and the environment.

Avoiding nanofoods and supporting a sustainable, just food system

- Avoid eating highly processed foods and eat more fresh food instead. Processed foods not only have higher environmental costs of production and have lower nutritional value, they are also a large source of incidentally produced nanoparticles in foods.
- Avoid highly packaged foods — packaging is energy intensive and produces lots of waste and is often unnecessary. Let your local food outlets and the manufacturers of your favourite foods know that you want to see less food packaging.
- Choose food that is healthy for you and the environment, and pays a fair wage to food producers. There are many simple steps we can all take to make food choices that are good for our health, good for the environment, and that support fair conditions for farmers.
- Make environmentally friendly food and farming choices — look out for the organic label at your supermarket or store.
- Support local food producers and small scale retailers and buy directly from local farmers, butchers and bakers. You could even consider joining a food co-operative or bulk-buying scheme.
- Support the right of communities to control local food trade, including deciding how food is grown, who can sell it and what can be imported.

Hold government and industry to account for nanofoods

- Write to your local representatives and members of state, federal and regional government, requesting their support for a moratorium on the use of all nanotechnology in the food sector. Demand that governments regulate and label food, food packaging and agricultural products that contain manufactured nanomaterials before allowing any further commercial sales.
- Ensure that food and agricultural manufacturers take seriously public concerns about nanofoods. Contact the manufacturers of foods you eat often and ask them about what steps they are taking to keep unsafe, untested nanomaterials out of the food they sell.
- Insist that governments and industry take seriously the risks of occupational exposure to nanomaterials for food and agricultural workers. If you are concerned about nano-exposure in your work place, talk with your colleagues or your union representative about opportunities for collective action to secure a safe work place.
- Contact civil society organizations you think may be interested in taking action to ensure precautionary management of the use of nanotechnology in food and agriculture applications. Find out what environment, public health, farmers and civil liberties organizations in your neighborhood are doing to work towards alternative food systems that deliver positive environmental and social outcomes.

Visit our website to learn more about nanotechnology or to support our work for safe food, and a just, resilient and sustainable food system.

Friends of the Earth-United States
http://www.foe.org/projects/food-and-technology/nanotechnology

1. INTRODUCTION

In the past three decades the number of food products available to the American public has grown immensely. While our modern food system has brought about an ever-increasing variety of "food" options for consumers to purchase, this increased variety has also delivered the burden of potentially harmful ingredients—most recently, nanomaterials.

Nanomaterials are produced by way of nanotechnology and are now found in a broad range of products. According to the Woodrow Wilson International Center for Scholars, foods containing nanomaterials are rapidly entering the market at a rate of three to four per week.

In 2008, Friends of the Earth released a groundbreaking report on the use of nanomaterials in food and agriculture, "Out of the laboratory and onto our plates: Nanotechnology in food and agriculture." Six years later, the U.S. government has made little progress in protecting the public from these potentially hazardous food ingredients, despite the fact that the number of "nanofoods" on the market has grown more than tenfold in six years. Due to a lack of required labeling and disclosure, the number of undisclosed nanomaterials in food is likely much greater. Simultaneously, an increasingly large body of peer-reviewed evidence indicates some nanomaterials, including those used in our food system, may harm human health and the environment.

This rapid introduction of nanomaterials into our food system has been driven by billions of dollars of investment by roughly 200 transnational food companies in nanofood and nanopackaging, with the nanofoods market expected to grow to US$20.4 billion by 2020.

Unfortunately, many food items that Americans eat on a daily basis contain nanomaterial ingredients. These include familiar products such as processed and cream cheeses, cookies, doughnuts, coffee creamer, chocolate syrup and other chocolate products, pudding, mayonnaise, mashed potatoes, milk, soy, almond, and rice beverages, mints, gum, popcorn, salad dressing and oils, yogurt, cereal, candy, crackers, pasta, and sports drinks. There is also mounting evidence that suggests nanomaterials are being used to package and preserve fresh fruit and vegetable products, a dangerous trend that could threaten the integrity of staple healthy foods. These products are manufactured and sold by major food companiesincluding Kraft, General Mills, Hershey, Nestle, Mars, Unilever, Smucker's and Albertsons. Due to a lack of required labeling and disclosure, the number of undisclosed nanomaterials in food is likely much greater.

This report will examine the rapid increase in nanomaterials entering our food system since the release of our 2008 report, including the development of new food and food-contact nano-products. It will provide a review of trends in nanotechnology and of the current literature relating to the potential environmental, health and safety impacts associated with nanotechnology and a summary of United States regulatory responses to date.

Six years ago, inaction on this issue was based on a perceived lack of data. Inaction is still the norm, but the lack of data is no longer an excuse that regulators and industry can use. While it is certainly true that environmental, health and safety research is not keeping with the pace of commercialization, the volume of information and studies now available is enormous. Governments, scientists and scientific bodies such as the U.S. National Research Council have presented more than sufficient evidence to justify a proactive regulatory regime and a properly funded research program that will effectively target those areas of greatest environmental and health concern.

A growing number of civil society organizations worldwide have called for precautionary management of nanotechnology, culminating in the release of “Principles for the Oversight of Nanotechnologies and Nanomaterials.”[1] More than 70 groups from six continents have endorsed this document.

Unfortunately, there is little sign of willingness by government to provide the levels of funding required to support such work or to adopt appropriate regulation. The notion of precaution has been replaced with an attitude that it is the obligation of industry to determine whether their products are safe and that regulators will only act when harm is shown. While France, Belgium and Denmark have implemented a mandatory register for nanomaterials, and the EU is in the process of implementing a nanofood labeling regime, which begins this year, U.S. consumers remain in the dark.

This situation will need to change if we are to protect consumers and our environment.

What is nanotechnology?

The term “nanotechnology” does not describe a singular technology, but rather encompasses a range of technologies that operate at the scale of the building blocks of biological and manufactured materials — the “nanoscale.”

There is still no internationally accepted set of definitions and measurement systems for nanotechnology, although work towards these has begun. However, the term “nanotechnology” is now generally understood to encompass both nanoscience and the broad range of technologies that operate at the nanoscale.

- **Nanoscience:** The study of phenomena and materials at the atomic, molecular and macromolecular scales, where properties differ significantly from those at the larger scale.
- **Nanotechnology:** design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanoscale.
- **Nanomaterials:** particles, nanotubes, nanowires, quantum dots, fullerenes (buckyballs) etc.

To put the nanoscale in context:

a strand of DNA is 2.5 nm wide, a red blood cell 7,000 nm and a human hair is 80,000 nm wide. One nanometer is one billionth of a meter. One way to understand how incredibly tiny these particles are is to consider a tennis ball in comparison with planet Earth. On scale, a tennis ball is the same size in relation to Earth as a nanoparticle is to a tennis ball.

Definition of nanomaterials for health and safety assessment

It should be noted that there exists an emerging trend to define nanotechnology as only applying to materials, structures and systems that measure no more than 100 nm in size. This distinction is quite artificial, especially from the viewpoint of biological interactions. The definition of nanomaterials is still in flux: the U.S. Food and Drug Administration uses a definition of 1-1,000 nm for drugs and requests information for ingredients less than 1,000 nm in size for other products it regulates. The European

Medicines Agency also defines nanotechnology in a size range of less than 1,000 nm across. Many small particles, which measure more than 100 nm present a similar suite of physiological and anatomical behaviors, for example greater reactivity, bioactivity and bioavailability.[2] When considering the health and environmental implications of nanoparticles, their size range must be more broadly defined. It is essential to also consider the hazards associated with sub-micron (100-1,000 nm) particles, and microparticles (greater than 1,000nm).

In a 2010 report, the UK's House of Lords Science and Technology Committee recommended that any definition of a nanomaterial must be based on evidence for behavior that is different from that seen in the bulk, rather than some arbitrary size such as 100 nm.[3] The authors of a review of the nanotoxicological implications of nanomedicines suggest that: "In practice, the useful range of nanomedicines more normally falls within the range of 5-250 nm as these tend to have a similar range of properties based on physiological and anatomical consequences."[4] Researchers investigating the biological effects of nanoparticles have also defined their relevant size range to be up to a few hundred nanometres.[5] Still other researchers publishing in the drug delivery[6] and food[7,8] literature have argued that a useful size definition for nanomaterials used in these fields is 1-1,000nm.

The problematic nature of the arbitrary 100 nm ceiling on what is considered to be a nanoparticle or nanomaterial for the purposes of future health and safety assessments is underscored by studies showing that small particles outside this size range can pose greater health hazards than particles within it. Wang et al conducted an *in vivo* study in which 20 nm and 120 nm particles of zinc oxide powder were fed to mice.[9] Both nanoparticles resulted in organ damage and thickening of the test animals' blood, but it appeared that the larger nanoparticles actually resulted in greater liver damage. In another *in vivo* experiment, mice were fed high doses of 58 nm and 1,058 nm zinc powder. The microparticle zinc caused more severe liver damage, while the nanoparticle zinc caused anaemia and more severe kidney damage.[10]

For the purpose of this report we use the term "nano" to include particles up to 1,000 nm in size, due to the evidence of nano-specific problems associated with particles up to this size range. We urge regulators to also adopt this definition to assess and manage the health and environmental hazards of nanoparticles. The health and environmental hazards of nanoparticles should be based on physiological and anatomical behaviors of small particles, rather than arbitrary size distinctions.

Manufactured vs. incidental nanoparticles

Manufactured nanoparticles are those which are deliberately produced, in contrast to nanoparticles that "exist in nature," or are by-products of other human activities. Manufactured nanomaterials include nanoparticles (e.g. metal oxides), and also nanostructures such as nanotubes, nanowires, quantum dots, dendrimers and carbon fullerenes (buckyballs), among others.

"Incidental" nanoparticles (also called ultrafine particles in the study of air pollution and its epidemiology) are a by-product of forest fires, volcanoes, vehicle combustion and high-temperature industrial processes including combustion, welding, and grinding.[11]

Much of the discussion about the health and environmental implications of nanoparticles is focused on manufactured nanoparticles. However, many of the safety and regulatory issues relating to manufactured nanoparticles are also relevant to incidentally produced nanoparticles. For example, we know that exposure to large levels of incidental nanoparticles in urban air pollution causes increased incidence of disease and even death among vulnerable sections of the population.[12] It is important to ensure that workers, the public and environmental systems are protected from unsafe exposure to and production of incidental nanoparticles.

Nanomaterials are already used widely for their novel properties

At the nanoscale, the physical, chemical and optical properties of familiar substances differ from those of the substances in larger particle form. For example, in larger particle form zinc oxide is white and opaque; as a nanoparticle zinc oxide is transparent, enabling it to be used to provide UV protection in products such as transparent cling wrap packaging. In nanoparticle form, the antimicrobial properties of silver are far greater, a property which has encouraged manufacturers to use it in chopping boards, refrigerators, food storage containers and food packaging.

Altered properties of nanoparticles are a result of both the influence of "quantum mechanics" and the much greater relative surface area that nanomaterials have compared with larger particles. The large surface area of nanomaterials results in their increased chemical reactivity and biological activity,[13] making them attractive for use in food fortification or as antimicrobials in food packaging. However, the altered properties of nanomaterials, especially their high chemical reactivity and greater capacity to penetrate biological membranes, also present serious new toxicity risks.[14]

Nanomaterials are 'first generation' products of nanotechnology and have been the first nanoproducts to enter wide-scale commercial use. They are used in hundreds of products that are already available on supermarket shelves, including transparent sunscreens, light-diffracting cosmetics, penetration enhanced moisturisers, stain, moisture and odor repellent fabrics, long lasting paints and furniture varnishes, anti-bacterial household appliances such as vacuum cleaners, refrigerators and air conditioners, and sporting equipment.[15]

In coming years and decades, "next generation nanotechnology" is forecast to bring more complex nanodevices, nanosystems and nanomachines.[16] Nanobiotechnology may be used to manipulate the genetics of human, animals and agricultural plants at the atomic scale, and to incorporate synthetic materials into biological organisms and biological materials into synthetic structures.[17]

Why are food and agriculture companies interested in nanotechnology?

Nanotechnology has existing and potential applications in all aspects of agriculture, food processing, food packaging and even farm and food monitoring. These include:

- Methods to enable foods such as soft drinks, ice cream, chocolate or chips to be marketed as "health" foods by reducing fat, carbohydrate or calorie content or by increasing protein, fiber or vitamin content;
- Production of stronger flavorings, colorings, nutritional additives and processing aids to increase the pace of manufacturing and to lower costs of ingredients and processing;
- Development of foods capable of changing their color, flavor or nutritional properties according to a person's dietary needs, allergies or taste preferences;
- Packaging to increase food shelf life by detecting spoilage, bacteria, or the loss of food nutrient, and to release antimicrobials, flavors, colors or nutritional supplements in response;
- Reformulation of on-farm inputs to produce more potent fertilizers, plant growth treatments and pesticides that respond to specific conditions or targets.

Edible food coatings

Manipulation of materials at the nanoscale can allow food scientists to create "edible nanolaminate films" which can be used as barrier layers to prolong shelf life. These films can include lipids or clays as moisture barriers, biopolymers such as carbohydrates as oxygen and carbon dioxide barriers, or nanoparticulates and emulsified nanodroplets, which could contain active ingredients to improve taste, texture or appearance. Antibacterial substances can also be directly integrated into the edible coating, for instance for meat packaging.[18]

Edible coatings containing engineered nanomaterials are reportedly already being used on fruit and vegetables in markets in the U.S. and Canada in order to extend shelf life. Tests conducted in Central and South American farms and packing stations found a number of fruits with a nano coating, including apples, pears, peppers, cucumbers and other fruits and vegetables delivered to the U.S. and Canada.[19]

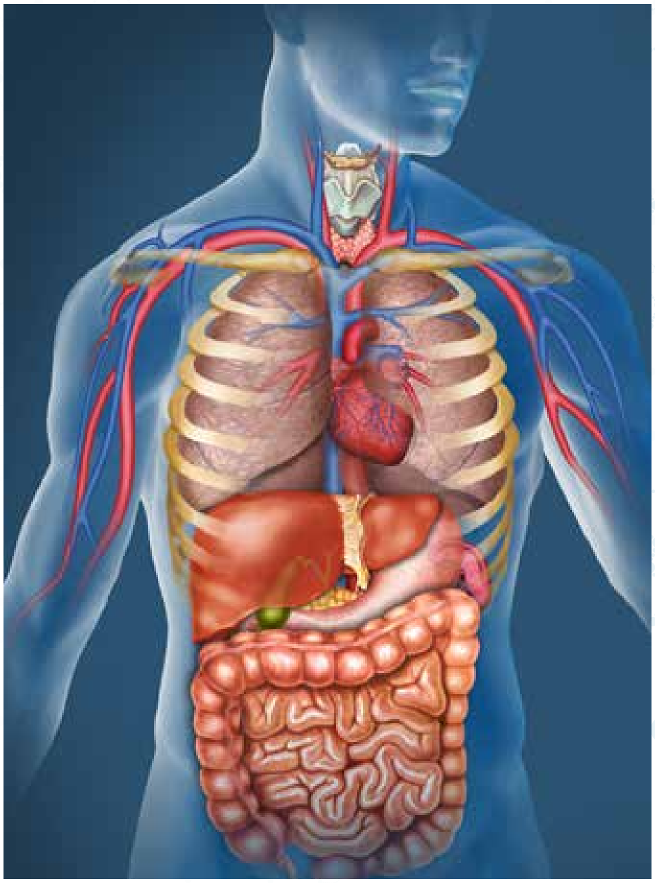
The complexity involved in detecting nanomaterials in our food

The detection of nanomaterials is a complex matter requiring state-of-the-art as well as experimental devices and techniques, especially when attempting to quantify or characterize nanomaterials in a complex matrix such as food. The lack of standards and internationally recognized measurement methods, coupled with the shrouding of the nanotechnology industry and reinforced by the lack of regulation in this area, have created significant challenges to simply understanding where nanomaterials are being used and the reality of their interactions with the public and our environment.

2. HEALTH CONCERNS: WHY NANOMATERIALS AND NANOFOODS POSE NEW RISKS

Nanomaterials have unique properties that offer many new opportunities for food industry applications, such as potent nutritional additives, stronger flavorings and colorings, or antibacterial ingredients for food packaging. However, the same properties exhibited at the nanoscale that make these materials attractive for use in the food industry may also result in greater toxicity for humans and the environment. Nanoparticles pose new risks because:

- They can be more chemically reactive and more bioactive than larger particles of the same chemicals.
- Due to their very small size, nanoparticles also have much greater access to our bodies, so they are more likely than larger particles to enter cells, tissues and organs.
- Greater bioavailability and greater bioactivity may introduce new toxicity risks.
- They can compromise our immune system response.
- They may have long-term pathological effects.



Nanoparticles of silver, titanium dioxide, zinc and zinc oxide, materials now used in nutritional supplements, food packaging and food contact materials, have been found to be highly toxic to cells in test tube and animal studies. Preliminary environmental studies also suggest that these substances may be toxic to ecologically important species such as water fleas. Yet there is still no nanotechnology-specific regulation or safety assessment required before manufactured nanomaterials can be used in food, food packaging, or agricultural products.

Before the industrial revolution humans faced very limited exposure to insoluble nanoparticles. Consequently, our bodies have not developed effective clearing mechanisms, as we have with larger particles, to remove them from our lungs, gastro-intestinal tract, tissues and organs,. Nanoparticles also show greater adhesion to biological surfaces within our bodies (for example, the walls of our gastrointestinal tract), which can increase rates of uptake.[20]

In the July 19, 2012, report, "Effects of Silver Nanoparticles on the Liver and Hepatocytes in vitro," published in Toxicological Sciences, author Birgit Gaiser, Ph.D., states,

> At the moment, there is not much information available on the topic of ingested nanoparticles and human health. There is evidence that a small percentage of these particles or particle components [of nano titanium dioxide or nano silver]…can move on from the intestinal tract into the blood, and reach other organs. This is why we believe it is important to assess the risk of even small amounts of particles in the human body.[21]

In 2009, a team led by Roel Schins at the Environmental Health Research Institute in Düsseldorf, Germany, published research suggesting that some nanoparticles, including silica and titanium dioxide, can induce DNA damage in human intestinal cells.[22]

Specific health concerns with nanomaterials in food and food contact materials

Silica

Uses: Used as a "trickle and flow" aid in powdered food products, as a clearing agent in beer and wine, as a food additive (amorphous silica found to be nano) and as a food coating.

Health concerns: Nanosilica has been found in the livers of rats and mice after oral administration. In vitro studies show a significant percentage of the nanosilica remains undissolved and that "the presence of undissolved nanosilica particles in the gut in vivo is considered likely."[23,24] Animal studies have shown placental transfer and fetal uptake of silica. Scientists have warned that the enhanced sensitivity of the foetus may mean that even low doses of nanomaterials may cause adverse effects.[25]

Nano-silver

Uses: In the Woodrow Wilson inventory of nano products, silver is the most common nanomaterial mentioned in product descriptions.[26] A recent court case in the United States found that the use of nanosilver was "ubiquitous" and that there was no way for consumers to avoid exposure.[27] Food and food contact products identified as containing nanosilver include baby bottles, food containers, packaging, cutting boards, salad bowls, appliances, cutlery, ice trays, filtration devices and collapsible coolers. In agriculture it is used in poultry production and agricultural and aquacultural disinfectants.[28]

Health concerns: There is mounting evidence that nanosilver may have greater toxic effects when compared with bulk silver. Nano-silver can better penetrate biological barriers and attach itself to the outside of cells.[29] Nanoscale silver can also enter the bloodstream and reach all organs of the body, including the brain, heart, liver, kidneys, spleen, bone marrow and nervous tissue.

Animal studies have shown placental transfer and fetal uptake of nanosilver,[30] which is especially disturbing considering a recent study that found exposure to nano-silver caused zebra fish embryos to develop with head abnormalities and no eyes. Zebra fish have been widely used as a model organism for the study of embryological development in other vertebrates including humans.[31]

Health experts have also raised concerns that the widespread use of nano-silver in consumer products will further increase the problem of antibiotic-resistant superbugs.[32]

Titanium dioxide

Uses: A whitener and brightener in a range of food products

Health concerns: The European Chemicals Agency is currently reviewing the safety of titanium dioxide (including the nano form) because of concerns it may be harmful to the environment and human health.[33]

In contrast to bulk particles of titanium dioxide, nanoscale titanium dioxide is biologically very active. Studies show that titanium dioxide can damage DNA,[34] disrupt the function of cells, interfere with the defence activities of immune cells and, by adsorbing fragments of bacteria and "smuggling" them across the gastrointestinal tract, can provoke inflammation.[35,36,37,38,39,40] A single high oral dose of titanium dioxide nanoparticles was found to cause significant lesions in the kidneys and livers of female mice.[41]

In a 2010 study the German Federal Institute for Risk Assessment and the German Federal Environment Agency concluded that nanoscale titanium dioxide is a possible carcinogen if inhaled.[42]

Nano titanium dioxide is highly mobile in the body and has been detected in both humans and animals in the blood, liver and spleen.[43] A study using pregnant mice found that nanoparticles of titanium dioxide were transferred in utero to their offspring. This resulted in brain damage, nerve system damage and reduced sperm production in male offspring.[44]

A human exposure analysis of titanium dioxide through foods identified children in the 2.5 to 4.5 year age range as having the highest exposures because the titanium dioxide content of sweets is higher than any other food products. It also calculated that a typical exposure for a U.S. adult may be of the order of 1 mg of titanium per kilogram of body weight per day.[45]

Many of the products Friends of the Earth found to contain nanomaterials specifically contained nano titanium dioxide. In laboratory studies, nanoparticles of titanium dioxide have been found to be immunologically active, causing a reaction from the body's defensive system. Ashwood et al show that these particles may play an important role in the initiation or exacerbation of gastrointestinal inflammation, by adsorbing bacterial fragments and then carrying them across the gastrointestinal tract. Additionally, in 2013, a team led by Roel Schins at the Environmental Health Research Institute in Düsseldorf, Germany, published research suggesting that some nanoparticles, including silica and titanium dioxide, can induce DNA damage in human intestinal cells.

Zinc oxide (ZnO)

Uses: Surface coatings

Health Concerns: Nanoscale zinc oxide is toxic when ingested and has been found to cause lesions in the liver, pancreas, heart and stomach.[46] A recent review of the safety of nano zinc oxide by the European Commission's Scientific Committee for Consumer Safety stated that "clear positive toxic responses in some of these tests clearly indicate a potential for risk to humans."[47] Inhalation exposure of nano zinc oxide induces lung inflammation, leading the SCCS to conclude that "the use of ZnO (zinc oxide) nanoparticles in spray products cannot be considered safe."[48]

Copper

Uses: dietary supplements[49]

Health Concerns: The German Federal Institute for Risk Assessment compared the acute toxicity of micro-and nanoscale copper. No adverse effects were observed with microscale copper; however, nanoscale copper showed adverse effects on the kidney, spleen and liver of mice.[50]

Carbon Nanotubes

Uses: While there are no confirmed commercial food and food contact products containing carbon nanotubes, food packaging and food sensors containing carbon nanotubes have been developed.[51]

Health Concerns: The Australian National Industrial Chemical Notification and Assessment Scheme and Safe Work Australia, which reviewed the safety of carbon nanotubes, found that multi-walled carbon nanotubes "have been shown to induce mesothelioma in rodents."[52]

Nano supplements could cause health problems

The head of the nanotechnology research group at the United Kingdom's Central Science Laboratory warns of unpredictable effects of nanoparticles and nano encapsulated additives: "They can be absorbed faster than desired or affect the absorption of other nutrients. We still know very little, if anything at all."[53]

In 2009, based on the growing number of commercially available nano supplements, the Woodrow Wilson International Center for Scholars' project on emerging nanotechnologies found that in the U.S. the Food and Drug Administration had neither the regulatory power nor the scientific expertise to determine if these supplements were safe.[54]

Migration of nanomaterials from packaging

It is possible that nanomaterials could migrate from food packaging into foods. Polymers and chemical additives in conventional food packaging, such as bisphenol A and phthalates, are known to migrate from the packaging into food products.[55,56] The Institute of Food Science and Technology has expressed concern that manufactured nanomaterials are already being used in food packaging, despite migration rates and exposure risks remaining unknown.[57] To date there are only a few studies that have investigated the migration of nanomaterials from food packaging into food, and the results have been inconclusive.

Nanoparticles and the link to Crohn's disease and immune system dysfunction

It is well known that people with asthma are especially susceptible to air pollution. In effect, asthma sufferers act as the proverbial "canary in the coal mine," alerting those around them that air pollution levels are getting dangerously high. Scientists have more recently suggested that the growing prevalence of Crohn's disease — a damaging and chronic inflammation of the gastrointestinal tract that can lead to cancer — may be a similar warning signal in relation to microparticles in our food.[58]

The relationship between the development of Crohn's disease and factors such as genetic susceptibility, immune system health, psychological health and environmental factors including, exposure and physiological response to nano or microparticles, remains poorly understood. However, data indicate that the inflammation associated with Crohn's may be explained in part by an abnormal or exaggerated response to the individual's intestinal bacteria.

Numerous *in vivo* experiments using rats and mice have demonstrated gastrointestinal uptake of nanoparticles.[59,60,61,62,63] and small microparticles.[64,65,66] Pathological examination of human tissues suggests ingestion and translocation of microparticles up to 20 μm in size.[67,68]

The absorption rate of substances via the gastrointestinal tract appears to depend on properties such as size and surface structure. In one study looking at rats, the smaller the nanoparticles the higher the uptake via the digestive tract.[69] In another study mice were fed 4 nm gold particles. These were later detected in the liver, kidney, spleen, lung and brain. Larger particles (58 nm) remained in the gastrointestinal tract.[70]

Studies have shown that nanomaterials may affect the human intestine. When human colon cells were treated with nano-sized polystyrene, which is commonly used in food packaging, the cells became more permeable to iron.[71] Powell *et al* have observed that the daily exposure of people in the Western world to sub-micrometer-sized mineral particles has resulted in "pigmented cells" loaded with these particles in parts of the intestinal tract. The particles have been observed to be composed of aluminosilicates, titanium dioxide and a small percentage of non-aluminum-containing silicates such as silica (SiO2) and magnesium trisilicate (talc).[72]

Preliminary evidence suggests that existing levels of nanoparticles up to a few hundred nanometers in size in processed food may be associated with rising levels of immune system dysfunction and inflammation of the gastrointestinal tract, including Crohn's disease.[73,74,75,76] Individuals with Crohn's disease or colon cancer have been found with nanomaterials in their intestinal tissue.[77]

The reasons for the disproportionate incidence of Crohn's disease in the global north are still disputed, but it is possible that the high consumption of industrially processed foods plays a role.

Occupational health and safety concerns

In the food sector, workers may come into contact with nanomaterials during production, packaging, transport and waste disposal of food and agrochemicals.[78] To date, there is very little data relating to the exposure of workers to nanomaterials.

A number of nanomaterials used in the food industry, such as zinc oxide and titanium dioxide, have been shown to be harmful when inhaled, raising OHS concerns for workers handling these materials.[79] However, in the absence of a mandatory register and product labeling, many workers may be unaware that they are handling nanomaterials and of the need to use protective equipment.

Studies have also shown that nanomaterials can enter the bloodstream via the lungs, raising major OHS concerns.[80]

Based on a 2009 review of carbon nanotubes by Safe Work Australia and NICNAS, carbon nanotubes were declared a hazardous chemical for purposes of health and safety laws.[81] This ruling does not prohibit their use, but it means that carbon nanotubes used in the workplace must be accompanied by a data safety sheet.

3. NANOFOODS ON THE MARKET

Our knowledge of the extent to which nanomaterials are used in food products is limited. Food manufacturers are not required to disclose details about their use of nanomaterials; nor is this information collected by the Food and Drug Administration. This, coupled with the lack of labeling laws, means the public is left to guess which products contain nanomaterials. The absence of transparency creates a chasm of knowledge not just for the public, but also for government regulators and even some food producers.[82]

Nevertheless, we do know that major food companies are involved in nanotechnology research and development; at least 200 transnational food companies are currently investing in nanotech and are on their way to commercializing products.[83] The nanofoods market is expected to grow to US$20.4 billion in 2020.[84] Table 1 shows a sample of food companies engaged in nanotechnology research and development.

Table 1: A sample of food companies engaged in nanotechnology research and development [85,86,87]

COMPANY	
• Altria (Mondelez)	• H.J. Heinz
• Associated British Foods	• Hershey Foods
• Ajinomoto	• La Doria
• BASF	• Maruha
• Cadbury Schweppes	• McCain Foods
• Campbell Soup	• Mars, Inc.
• Cargill	• Nestle
• DuPont Food Industry Solutions	• Northern Foods
• General Mills	• Nichirei
• Glaxo-SmithKline	• Nippon Suisan Kaisha
• Goodman Fielder	• PepsiCo
• Group Danone	• Sara Lee
• John Lust Group Plc	• Unilever
	• United Foods

Table 2: Food products that may contain manufactured nanomaterials [88]

PRODUCTS	
• Almond beverages	• Milk
• Candy	• Mints
• Cereal	• Oils
• Chocolate	• Pasta
• Chocolate syrup	• Popcorn
• Coffee Creamer	• Pudding
• Cookies	• Rice beverages
• Crackers	• Salad Dressing
• Cream Cheese	• Soy
• Doughnuts	• Soy beverages
• Gum	• Sports Drinks and other beverages
• Mashed Potatoes	• Yogurt
• Mayonnaise	

Many foods Americans eat on a daily basis contain nanomaterial ingredients (see Table 2 for a list of product types that may include nanomaterials). In 2008, Friends of the Earth released a groundbreaking report on the use of nanomaterials in food, "Out Of the Laboratory and Onto Our Plates: Nanotechnology in Food and Agriculture." Six years later, our government has made little progress in protecting the public from these potentially dangerous food ingredients, despite the fact that additional nanofoods continue to be found on the market.

While the FDA is charged with ensuring "the safety and security of our nation's food supply," at this time the agency has merely offered nonbinding guidance to industry on the use of nanomaterials in food.[89] However, the FDA's 2012 draft guidance on the use of nanomaterials in food warns about the different properties of nanomaterials compared to ingredients used in traditional manufactured food substances.[90] Nevertheless, lack of established regulations allow for nanofood products to remain on the market while the public takes up potential health risks.

Friends of the Earth has compiled a list of 87 food and beverage products known to contain nanomaterials (see Table 3 for a list of products that include nanomaterials). We have compiled an additional 79 products since our 2008 report. The number of nanofood products we know to be on the market has grown more than tenfold in six years.

Beyond food, nanomaterials are also found in kitchen equipment, health supplements, some types of agricultural inputs, food contact materials and food packaging, as well as in a broad range of other products. The use of nanomaterials in food contact materials, including packaging, cling wrap, storage containers and chopping boards, increases the probability of nanomaterial ingestion. It is also likely that nanomaterials in packaging that is not designed to release chemicals (for example, nanosilver antibacterial food storage containers) will nevertheless migrate from food packaging into foods. Polymers and chemical additives in conventional food packaging are known to migrate from the packaging into food products — such is the case with BPA and phthalates.[91,92] Conversely, flavors and nutrients in foods and beverages are also known to migrate into plastic packaging, a process known as "flavor scalping." Nanotechnology is also expected to dramatically expand the use of edible coatings, which will clearly result in increased ingestion of nanomaterials (see nano fruit case study).

Nanomaterials are already integrated into food labels that indicate the freshness or temperature of a food product via color-coded display stickers. The company OnVu™ creates "the label that makes freshness visible" and is already featured in U.S. supermarkets. The OnVu™ Intelligent indicator has been applied onto meat product labels.[93,94]

Nanofood products are also marketed for children and babies. Several products are commercially available in the form of powdered nutritional drinks (ToddlerHealth and NanoVM®).[95,96]

Table 3: Commercially available nanofoods

PRODUCT NAME	MANUFACTURER	NANO CONTENT
Albertsons American Single	Albertsons	Titanium dioxide
Albertsons Cheddar Cheese Stick	Albertsons	Titanium dioxide
Albertsons Chocolate Syrup	Albertsons	Titanium dioxide
Albertsons Chocolate Sandwich Cookies	Albertsons	Titanium dioxide
Albertsons Coffee Creamer	Albertsons	Titanium dioxide
Albertsons Cream Cheese	Albertsons	Titanium dioxide
Albertsons Golden Sandwich Cookies	Albertsons	Titanium dioxide
Albertsons Italian Cheese Blend	Albertsons	Titanium dioxide
Albertsons Mini MarshMallows	Albertsons	Titanium dioxide
Albertsons Mozarella Stick	Albertsons	Titanium dioxide
Albertsons Vanilla Pudding	Albertsons	Titanium dioxide
Albertsons Whipped Cream	Albertsons	Titanium dioxide
Best Foods Mayonnaise	Unilever	Titanium dioxide
Betty Croker Mashed Potatoes	General Mills	Titanium dioxide
Betty Croker Whipped Cream Frosting	General Mills	Titanium dioxide
Breathsavers Mints	Hershey’s	Titanium dioxide
Cadbury Milk Chocolate Bar	Hershey’s	Titanium dioxide
Canola Active Oil	Shemen Industries	Nano-sized self assembled structured liquids = micelles
Carnation Breakfast	Nestle	Titanium dioxide
Dentyne Fire Spicy Cinnamon	Mondelēz International	Titanium dioxide
Dentyne Ice Peppermint Gum	Mondelēz International	Titanium dioxide
Dickinson’s Coconut Curd	Dickinson’s	Titanium dioxide
Eclipse Spearmint Gum	Wrigley	Titanium dioxide
Fancy Flake Coconut	Spartan	Titanium dioxide
Fiber One Cereal	General Mills	Titanium dioxide
General Mills Trix Cereal	General Mills	Titanium dioxide
Good and Plenty Candy	Hershey’s	Titanium dioxide
Hershey’s Bliss Dark Chocolate	Hershey’s	Titanium dioxide
Hershey’s Bliss White Chocolate	Hershey’s	Titanium dioxide
Hershey’s Chocolate Syrup	Hershey’s	Titanium dioxide
Hershey’s Cookie n Cream Bar	Hershey’s	Titanium dioxide
Hershey’s Milk Chocolate Bar	Hershey’s	Titanium dioxide
Hershey’s Special Dark Bar	Hershey’s	Titanium dioxide

Table 3: Commercially available nanofoods (continued)

PRODUCT NAME	MANUFACTURER	NANO CONTENT
Hostess Frosted Donettes	Hostess	Titanium dioxide
Hostess Powdered Donettes*	Hostess	Titanium dioxide
Hostess Twinkies	Hostess	Titanium dioxide
Jello Banana Cream Pudding	Kraft	Titanium dioxide
Junior Mints	Tootsie	Titanium dioxide
Keebler Pepper Jack Crackers	Kellogg's	Titanium dioxide
Knorr Pasta Sides Pasta	Unilever	Titanium dioxide
Kool Aid Blue Raspberry	Kraft	Titanium dioxide
Kool Aid Lemonade	Kraft	Titanium dioxide
Kraft American Single	Kraft	Titanium dioxide
Kraft Easy Cheese	Kraft	Titanium dioxide
Kraft Jet Puffed FunMallows	Kraft	Titanium dioxide
Kraft Jet Puffed MarshMallows	Kraft	Titanium dioxide
Kraft Mayo	Kraft	Titanium dioxide
Kraft Miracle Whip	Kraft	Titanium dioxide
Kraft Parmesan Cheese	Kraft	Titanium dioxide
Kraft Velveeta	Kraft	Titanium dioxide
Lays Ranch Seasoning Mix	FritoLay	Titanium dioxide
Lindt Milk Chocolate	Lindt	Titanium dioxide
Lindt White Chocolate	Lindt	Titanium dioxide
M&Ms Chocolate Candy	Mars,Inc.	Titanium dioxide
M&Ms Chocolate with Peanuts	Mars,Inc.	Titanium dioxide
Maternal Water	La Posta del Aguila	Silver
Mentos Freshmint Gum	Perfetti Van Melle	Titanium dioxide
Mentos Mints	Perfetti Van Melle	Titanium dioxide
MesoGold®	Purest Colloids, Inc.	Titanium dioxide
Mini Whoppers Eggs	Hershey	Titanium dioxide
Minute Rice	Riviana Foods	Titanium dioxide
Mothers Oatmeal Iced Cookies	Kellogg's	Titanium dioxide
Nabisco Chips Ahoy	Kraft	Titanium dioxide
Nabisco Oreo	Kraft	Titanium dioxide
Nabisco Sugar Free Oreo	Kraft	Titanium dioxide
Nanoceuticals™ Slim Shake Chocolate	RBC Life Sciences®, Inc.	Titanium dioxide

Table 3: Commercially available nanofoods (continued)

PRODUCT NAME	MANUFACTURER	NANO CONTENT
Nanotea	Shenzhen Become Industry & Trade Co., Ltd.	Nano-ball milling procedures
Nestle French Vanilla Coffee Mate	Nestle	Titanium dioxide
Nestle Original Coffee Creamer	Nestle	Titanium dioxide
Peeps Marshmallows	Born Candy Co.	Titanium dioxide
Philadelphia Cream Cheese	Kraft	Titanium dioxide
Pina Colada Sobe	South Beach Beverage Co.,Inc.	Titanium dioxide
Powdered donuts*	Dunkin' Donuts	Titanium dioxide
Primea Ring	Saeco USA Inc.	Silver
Ragu Classic Alfredo	Unilever	Titanium dioxide
Richardson Pastel Mints	Richardson's	Titanium dioxide
Shamrock Farms Fat Free Milk	Shamrock Foods	Titanium dioxide
Smuckers Orange Cream Shell	Smuckers	Titanium dioxide
Tic Tac Mints	Ferrero	Titanium dioxide
Trident White Peppermint Gum	American Chicle	Titanium dioxide
Turkey Gravy		Titanium dioxide
Vanilla Milkshake Pop Tarts*	Kellogg's	Titanium dioxide
Vics White Cheddar Popcorn	Vic's Corn Popper	Titanium dioxide
White M&Ms*	Mars, Inc.	Titanium dioxide
Wishbone Ranch Dressing	Unilever	Titanium dioxide

Note: List based on the Project on Emerging Nanotechnologies' Consumer Products Inventory current as of Feb. 19, 2014.[97] However, manufacturers change their product formulation from time to time, and such changes may not be reflected in the database. Friends of the Earth has not conducted tests on these products and cannot guarantee their nanomaterial content; products marked with an asterisk have been found to contain nanomaterials via a laboratory study commissioned by As You Sow in 2013.[98]

Edible food coatings

Manipulation of materials at the nanoscale can allow food scientists to create "edible nanolaminate films" that can be used as barrier layers to prolong shelf life. These films can include lipids or clays as moisture barriers; biopolymers, such as carbohydrates, as oxygen and carbon dioxide barriers; or nanoparticulates and emulsified nanodroplets, which could contain active ingredients to improve taste, texture or appearance.[99] Antibacterial substances such as nanosilver can also be directly integrated into the edible coating, such as for meat packaging.[100]

Edible coatings containing engineered nanomaterials are reportedly already being used to extend the shelf life of fruit and vegetables in markets in the U.S. and Canada.[101] Tests conducted in Central and South American farms and packing stations found a number of fruits with a nano coating, including apples, pears, peppers, cucumbers and other produce that is delivered to the U.S. and Canada.[102]

4. NANOFOODS AND NANOAGRICULTURE POSE NEW ENVIRONMENTAL RISKS

Nanomaterials now in commercial use pose serious ecological hazards

Nanomaterials used in the agri-food system inevitably enter the environment from waste associated with product manufacture, product use (including ingestion and excretion) or disposal. Furthermore, nanomaterials are being released into the environment intentionally, for example as nano-agrochemicals and nano-feed used on farms. Early studies have demonstrated that nanomaterials already in commercial use pose serious hazards to species like largemouth bass and water fleas (*Daphnea magna*), which are used by regulators as ecological indicators (see Table 4).

Preliminary studies suggest that nanomaterials may accumulate (and possibly even magnify) in organisms along the food chain.[103,104] The extent to which nanomaterials will "clump" together in the environment, forming larger particles that may pose reduced toxicity risks, is unknown. The ecological hazards associated with nanotoxicity remain very poorly understood, underscoring the urgent need for further research.[105]

Friends of the Earth has expressed great concern about the environmental implications of the dramatically expanded use of nanosilver and other antimicrobial nanomaterials in consumer and industrial products.[106] Fullerenes,[107] nano titanium dioxide, nano zinc oxide,[108] nano-silver, single-walled carbon nanotubes[109] and other nanomaterials have all been found to have bactericidal properties. Yet the effects of nanomaterials on microbes, bacteria and fungi — the foundation of all ecosystems — remain poorly understood. Increased commercial use of highly potent anti-bacterial nanomaterials and their increased presence in waste streams could disrupt the functioning of beneficial bacteria in the wider environment, for example those performing nitrification and denitrification in freshwater and the marine environment.[110] Nano-antimicrobial agents may also shift into microbial populations and disrupt the functioning of nitrogen-fixing bacteria associated with plants.[111] Any significant disruption of nitrification, denitrification or nitrogen fixing processes could have serious negative impacts for the functioning of entire ecosystems. There is also a risk that widespread use of antimicrobials will result in greater antibiotic resistance among harmful bacterial populations.[112,113]

Early studies have demonstrated that nanomaterials already in commercial use pose serious hazards to important aquatic species.

Table 4: Experimental evidence of the ecotoxicity of nanomaterials now in commercial use

NANOMATERIAL AND CURRENT APPLICATIONS	SIZE AND PHYSICAL DESCRIPTION	EXPERIMENTAL EVIDENCE OF TOXICITY
Titanium dioxide Nano form used in sunscreens, self-cleaning glass, remediation, widely use in small micro form in foods and cosmetics	30nm	Killed water fleas (*Daphnea magna*)[114] which are used by regulators as an ecological indicator species
	25nm anatase	UV-illuminated $TiO2$ toxic to algae and water fleas[115]
Zinc Used in electronics, optoelectronics, gas sensors, sunscreens, cosmetics, food packaging, paint	Nanoparticle zinc oxide, size unknown	Toxic to algae and water fleas (*Daphnea magna*)[116]
Carbon based nanomaterials Carbon black used in tyres, dyes; carbon nanotubes used in specialist car and aeroplane materials and fabrics, potential use in packaging; fullerenes used in cosmetics, potential use in medicines, batteries and electronics	C60 fullerenes	Water soluble C60 caused brain damage (lipid peroxidation) in juvenile largemouth bass (*Micropterus salmoides*)[117], used by regulators as an ecological indicator. Subsequent study found tetrahydrofuran (THF)-solubilized fullerenes even more toxic than water solubilised fullerenes, with 100% mortality in the THF-C60-exposed fish between 6 and 18 hours of exposure[118]
	Single walled carbon nanotubes	By-products associated with their manufacture cause increased mortality and delayed development of small estuarine invertebrate *Amphiascus tenuiremis*[119]
	Single-walled carbon nanotubes	By-products associated with their manufacture delayed hatching of zebra fish (*Danio rerio*) embryos[120].
	C60 fullerenes	Killed water fleas (*Daphnea magna*)[121,122]
	C60 fullerenes and C60HxC70Hx	Caused behavioural and physiological changes in water fleas that are associated with increased risk of predation and reproductive decline[123]
	C60 fullerenes	Toxic to microbes, inhibits growth and decreases respiration[124]
Aluminium Used in cosmetics, sunscreens, scratch resistant coatings	13nm	High levels of exposure stunted root growth in corn, cucumber, soybean, carrot and cabbage crops[125]

The United Kingdom's Royal Society and Royal Academy of Engineering have called for the environmental release of nanomaterials to be "avoided as far as possible," and for their intentional release to "be prohibited until appropriate research has been undertaken and it can be demonstrated that the potential benefits outweigh the potential risks."[126]

In May 2013, a group of U.S. scientists published the first global assessment of the likely emissions of nanomaterials into the environment and landfills. It was estimated that in 2010, 260,000 to 309,000 metric tons of global nanomaterial production were discarded into landfills (63-91 percent), soils (8-28percent), water bodies (0.4-7 percent), and the atmosphere (0.1-1.5percent). According to the authors, more accurate estimates of nanomaterial emissions were hampered by the lack of available data on use.

The annual worldwide market for nanomaterials is estimated to be around 11 million metric ton. By far the largest share of the nanomaterials currently on the market is industrial carbon (85 percent by weight) and silica (12 percent by weight). Nanoscale titanium and nano-silver are believed to be the most-used nanomaterials in food and food contact materials.[127]

As the European Commission's Scientific Committee on Emerging and Newly Identified Health Risks has noted, "the increasing use of Ag-NPs [nanosilver] in consumer and medical applications implies that they will find their way into the environment. The activity that makes them desirable as an antimicrobial agent could also pose a threat to the microbial communities in the environment."[128]

Impacts on aquatic ecosystems

A recent review of toxicological research on nanometal oxides silver, copper and zinc oxide reported that they are extremely toxic to freshwater aquatic organisms including fish and algae, with crustaceans being most affected.[129]

Titanium dioxide, one of the most widely used nanomaterials, caused organ pathologies, biochemical disturbances and respiratory distress in rainbow trout.[130] Nano titanium dioxide is also toxic to algae and to water fleas, especially after exposure to UV light.[131,132]

Impacts on soils

According to a U.S. study, emissions to soils represent as much as a quarter of nanomaterial flows, mostly from the disposal of biosolids onto agricultural land.[133] This is troubling because studies have shown that nanomaterials can potentially harm beneficial soil microorganisms, plants, nematodes and earthworms and prevent nitrogen fixation.[134,135,136]

Another recent U.S. study found that metal and metal oxide nanoparticles accumulate in the soils to which they are applied, rather than aggregating or dissolving, and can be toxic to microorganisms, plants, nematodes and earthworms.[137] Similar adverse effects on earthworms have been observed in reaction to other nanoparticles.[138]

A recent study by Colman et al. found an adverse impact on plants and microorganisms in a long-term field experiment following the application of sewage biosolids containing a low dose of nano-silver.[139] The nano-silver treatment led to changes in microbial community composition, biomass and extracellular enzyme activity, and affected some of the above-ground plant species, as well. It also led to an increase in nitrous oxide (N2O) fluxes — significant because nitrous oxide is a notorious greenhouse gas, with 296 times the global warming potential of carbon dioxide.

Any significant disruption of nitrification, denitrification or nitrogen fixing processes could have negative impacts for the functioning of entire ecosystems. There is also a risk that widespread use of antimicrobials will result in greater antibiotic-resistance among harmful bacterial populations.[140]

Bioaccumulation of nanomaterials

A number of studies have shown that plant species can take up nanomaterials from soils.[141] This suggests a potential route for nanomaterials from sewage waste to return to the food chain. A recent report by the European Environment Agency concluded that "the extent to which specific nanomaterials are bioaccumulative or lead to irreversible impact is largely unknown, but the current state of knowledge suggest[s] that the potential exists for such behavior under some circumstances."[142]

Risks from pesticides with nanoscale active ingredients

The use of pesticides with nanoscale active ingredients may pose particular risks because nanomaterials, which are more potent and behave differently than conventional chemicals, are applied in large quantities and over large areas in industrial agriculture.

The term "nanopesticide" covers a wide variety of products and cannot be considered to represent a single category. Many nanoformulations combine several surfactants, polymers and metal nanoparticles in the nanometer size range.[143]

Conventional agrochemicals, such as pesticides, fertilizers and seed treatments, have already contributed to soil and water pollution, caused significant disturbance of ecosystems and driven a loss of biodiversity.[144] It is feared that the broad use of nano-chemicals will exacerbate existing problems.

The claim that nano agrochemicals will reduce the overall use of pesticides should be approached sceptically, given similar unfulfilled promises made by many of the same companies in relation to genetically modified crops.

Nanotechnology also appears likely to intensify existing trends toward ever-larger industrial-scale farming operations, and an even more narrow focus on producing specialized crops.[145,146] This could lead to further losses of agricultural and ecological diversity.

The intentional environmental release of nano-agrochemicals is of great concern

Nano-formulations of existing agrochemicals may be more reactive, more bioactive and may introduce even more serious environment and health hazards than the conventional agrochemicals they replace. The use of nanoscale agrochemicals is of great concern given the extremely limited understanding we have of how nano herbicides, pesticides, fertilizers and plant growth treatments will behave in the environment and will affect non-target organisms, and the potential for serious eco-nanotoxicological hazards indicated by the small number of studies that has been carried out to date. It appears we are on the verge of repeating many of the mistakes associated with our enthusiastic adoption of conventional agrochemicals, whose long-term health and environmental costs are borne by farming communities and ecological systems worldwide.

Conventional agrochemicals have polluted soils and waterways and have caused substantial disruption to these ecosystems.[147,148,149] Exposure to agrochemicals has also been linked with greater incidence of cancer and serious reproductive problems among agricultural workers and their families.[150,151,152] It is consequently of great concern that nano-agrochemicals are now being used on farms and released into the environment in the absence of regulations that require product manufacturers to demonstrate the safety of new, more potent nanoscale formulations of existing chemicals.

Perhaps ironically, there is a large degree of interest in the use of nanomaterials for environmental remediation, including cleanup of toxic plumes associated with past use of agricultural pesticides.[153] Dozens of sites in the United States, Europe and elsewhere have already been injected with tens of metric tons of nanoparticles for environmental remediation or waste treatment purposes,[154] despite no study having being carried out to assess the efficacy of these experiments and the safety of these nanoparticles for environmentally relevant species.[155]

There is little published, peer-reviewed information available about the outcomes of these releases; they are, however, of serious concern given early indications that nanomaterials present a whole new range of serious ecological threats.[156] The United Kingdom's Royal Society and Royal Academy of Engineering have warned that using nanomaterials in remediation of toxic plumes could introduce a whole new set of environmental pollutants that pose even greater ecological hazards. They have called for the environmental release of nanoparticles to be "avoided as far as possible," and for their intentional release for pollution remediation or other purposes to "be prohibited until appropriate research has been undertaken and it can be demonstrated that the potential benefits outweigh the potential risks."[157]

Nanobiotechnology and synthetic biology pose even more uncertain hazards

Next-generation agricultural nanoproducts — crops manipulated using nanobiotechnology, for example, or synthetic biology organisms developed to assist in the production of biofuels — will present even more complex ecological hazards than those associated with nano-agrochemicals. Genetic engineering is a technology that transfers genes from one species to another in a way that does not occur naturally. As nanoparticles are now being used by biotechnologists as a new tool for genetic engineering of plants and animals, many of the potential ecological hazards associated with nanobiotechnology-manipulated crops mirror those associated with genetically engineered organisms. These include the potential for use of herbicide-tolerant, insect- or virus-resistant GE crops to result in: increased weediness of wild relatives; development of herbicide/insect/virus resistance among crops; negative impact on animal populations through reduced food availability; development of more virulent and difficult-to-control viruses; toxicity to non-target species; ecosystem-level disruption as a result of any or all of these.[158]

Despite the rapid commercial expansion of GE crops and the failure of the industry to prevent widespread genetic contamination of GE-free crops,[159] the ecosystem-level impacts of genetic engineering remain very poorly understood. Batie observes that whereas research has demonstrated that GE crops can adversely impact lacewings, monarch butterflies, ladybugs and soil biota, and modelling has predicted a dramatic decline in the European skylark if there is widespread adoption of GE herbicide-tolerant sugar beets, it could take decades of larger-scale ecological monitoring to identify the ecosystem impacts of GE crop use.[160] And our capacity to identify GE crop-driven ecological change is undermined by the wholly inadequate monitoring of environmental effects at field or ecosystem scales.[161]

In addition to the potential environmental hazards, there is also concern that aggressive global marketing of a small number of high-tech crops will result in further displacement of regional crop varieties, and further erosion of agricultural diversity. Moreover, herbicide-tolerant and pesticide-exuding crops not only entrench our dependence on toxic chemicals for farm management, they are also likely to reduce on-farm biodiversity, for example among beneficial insects and birds. Reliance on crops designed to withstand greater applications of agrochemicals, or to themselves exude pesticides, takes us further from establishing the ecologically safe integrated pest management systems that characterize organic and agro-ecological farming models.

The environmental and biosafety risks associated with the emerging field of synthetic biology are even harder to quantify, let alone control. Synthetic biology is an extreme form of genetic engineering, in which scientists write entirely new genetic code on a computer, "print" it out and then insert it into organisms to serve specific functions. Synthetic biology organisms are being developed for agriculture, biofuels and energy production, nutraceuticals and food processing, carbon sequestration, environmental remediation, medicine, manufacturing and military applications, among others.[162] Many synthetic biology organisms are being developed for intentional environmental release. The wide-scale and worldwide genetic contamination of both GE-free crops and GE-free food processing[163] highlight the difficulties of preventing contamination in an industry that involves self-replicating organisms and millions of people. It suggests that we will fail in attempts to contain synthetic biology organisms.

If released into the environment intentionally or accidentally, synthetic biology organisms could present a range of serious ecological hazards. These include the potential for disruption, displacement or infection of other species; alteration of the environment in which they were introduced, to the extent that ecosystem function is compromised; and establishment within a system such that they become impossible to eliminate.[164] Many synthetic biologists working with fairly simple genetic circuits report rapid mutation of the circuits as a key challenge to their work. The potential for synthetic biology organisms released into the environment to mutate in unpredictable ways is of great concern. For example, the worst-case scenario of an accidental introduction into the environment of a synthetic biology organism designed to turn corn waste into ethanol could be catastrophic.

Nanotechnology in agriculture and food production has broader environmental costs

Perhaps the most insidious environmental impact associated with the expansion of nanotechnology in agriculture is its entrenching our reliance on the dominant chemical-intensive industrial agricultural model. Nanotechnology will intensify the key characteristics of this agricultural model, including trends toward ever-larger farming operations, an even narrower focus on producing specialized crops, further loss of agricultural and ecological diversity, an even greater dependence on chemical inputs and an even more atomized approach to farm management. The net result will be that we move further from real farming, where a key emphasis is maintaining and enhancing agricultural and ecological diversity, and an agricultural alternative which has been demonstrated to deliver a range of other environmental benefits, including reduced use of water and fossil fuel energy, higher soil organic matter and nitrogen, and reduced soil erosion. Moreover, 60 international experts at the United Nations agree that "the world currently already produces sufficient calories per head to feed a global population of 12 to 14 billion."[165] The UN's research confirms that "hunger and malnutrition are not phenomena of insufficient physical supply, but results of prevailing poverty, and above all problems of access to food."[166] According to a 2013 report by the Institute for Agriculture and Trade Policy, "there is no informed, broad-based constituency to support regulating ENMs [engineered nanomaterials] in fertilizers and biosolids to protect soil health and soil biodiversity."[167]

The expansion of nanotechnology in food processing and packaging will also result in a higher ecological footprint as food travels farther and is even more highly processed, requiring ever greater energy inputs. The United States agri-food system already uses more than 10,551 quadrillion Joules of energy each year, as much as France's total annual energy consumption. Agriculture — growing food — accounts for only 20 percent of this; 80 percent of the energy is used to move, process, package, sell and store food after it leaves the farm.[168] Incredibly, processing breakfast cereals requires 3,232 kilocalories per kilogram — five times the energy contained in the cereal itself.[169] Nano foods will be even more highly processed than today, requiring even greater energy inputs to produce. Similarly, nano food packaging, which has a primary goal of extending the shelf life of packaged food, will inevitably encourage manufacturers to transport food over even greater distances, resulting in an increase in food transport-related greenhouse gas emissions.

5. NANOFOOD REGULATORY GAPS MUST BE URGENTLY ADDRESSED

While the U.S. FDA is charged with ensuring "the safety and security of our nation's food supply," at this time the agency has merely offered nonbinding guidance to industry on the use of nanomaterials in food. However, the agency's 2012 draft guidance on the use of nanomaterials in food warns about the different properties of nanomaterials compared to ingredients used in traditional manufactured food substances. Nevertheless, lack of established regulations allow nanofood products to remain on the market while the public takes up potential health risks.

A growing number of civil society organizations worldwide have called for precautionary management of nanotechnology. This has included the release of "Principles for the Oversight of Nanotechnologies and Nanomaterials,"[170] endorsed by more than 70 groups from six continents.[171] Additionally, the President's Council of Advisors on Science and Technology, in its 2013 assessment of the National Nanotechnology Initiative, expressed concerns about "a lack of integration between nanotechnology-related [environmental health and safety] research funded through the NNI and the kind of information policymakers need to effectively manage potential risks from nanoparticles."[172]

Because of health concerns, bans on nanoparticles in food have been enacted by the largest organic certifiers in several countries, including the UK's Soil Association,[173] Biological Farmers of Australia[174] and the Canada General Standards Board.[175]

The U.S. Environmental Protection Agency has legal powers to compel nano agrochemicals manufacturers to provide toxicity data and to demonstrate product safety — that is, to place the burden of proof on the manufacturers.[176] Producers of pesticide products must submit scientific and technical data for EPA review; however, according to a U.S. General Accountability Office report, "EPA estimated that companies provided information on only about 10 percent of the nanomaterials that are likely to be commercially available.[177] EPA also reported that in its review of data submitted through its data collection program there were instances in which the details of the manufacturing, processing, and use of the nanomaterials, as well as exposure and toxicity data, were not provided."[178]

Moreover, the extent to which nanomaterials are used along the food chain continues to be shrouded in mystery because of the lack of publicly accessible product registries or product labels made mandatory by our regulators, leaving consumers, workers, other companies along the supply chain and even regulators in the dark.

A growing number of civil society organizations worldwide have called for precautionary management of nanotechnology.

6. URGENTLY NEEDED RESEARCH

Scientists currently lack the information and tools necessary to do basic risk assessments for most nanomaterials. The European Food Safety Authority has admitted that risk assessments for nano-products in food and feed will inevitably have significant uncertainties, because testing methods and data on risk and exposure are missing.[179]

In relation to food, there are significant gaps in our knowledge, including information on:

- The extent to which nanomaterials from packaging, surfaces and coatings migrate into foods.
- Where nanomaterials are distributed in the human body following ingestion.
- The long-term chronic effects of ingesting nanomaterials, including impacts on sensitive populations.
- How nanomaterials interact with the human body and in the environment.[180]
- How, where and in what quantities nanomaterials enter the environment.[181]
- Once nanomaterials are released, how durable they are and the extent to which they are transformed in the environment.[182,183]
- The fate, behavior and ecotoxicity of nanomaterials throughout their life cycle. How to characterize, track and detect nanomaterials in complex environments.[184]

In 2012, the U.S. National Research Council set out an environment, health and safety research strategy for beginning to deal with the gigantic gaps in knowledge surrounding the environmental and human health impacts of nanomaterials. That research strategy became part of the National Nanotechnology Initiative in the U.S. in what was supposed to be an integrated, collaborative effort by many departments to ensure that the development of nanotechnology industries was done well.

A year later, the NRC report, "Research Progress on EHS Aspects of Engineered Nanomaterials,"[185] analyzed progress to date. Of the 20 indicators NRC used to assess progress, there has been little or no progress in 19. The report noted that "despite increasing budgets for nanotechnology-EHS research and a growing number of publications, regulators, decision makers and consumers still lack the information needed to make informed public health and environmental policy and regulatory decisions."[186]

These are not simply arcane research priorities; they are the basic research and knowledge needed to understand, identify, assess, control and remediate potential impacts. It is the kind of knowledge that is necessary if we are going to have coherent regulation ensures nanoproducts that are not safe are not released, and that if unpredicted impacts occur we have the tools to deal with them.

7. RECOMMENDATIONS

Given the potentially serious health and environmental risks and social implications associated with nanofoods, Friends of the Earth is calling 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 and labeling laws are established and the public is involved in decision making.

Nanomaterials must be regulated as new substances. Transparency in safety assessment and product labeling is essential.

What government must do:

Nanomaterials must be regulated as new substances.

- All manufactured nanomaterials must be subject to safety assessments as new substances, even where the properties of their larger-scale counterparts are well known.
- All deliberately manufactured nanomaterials must be subject to rigorous nano-specific health and environmental impact assessments and demonstrated to be safe prior to approval for commercial use in foods, food packaging, food contact materials or agricultural applications.
- Assessments must be based on the precautionary principle and the onus must be on manufacturers to comprehensively demonstrate the safety of their product. No data, no market.
- Safety assessments must be based on the nano content of products, not marketing claims.
- Safety assessments must include the product's entire life cycle.

The size-based definition of nanomaterials must be extended.

- All particles up to 1,000nm in size must be considered to be "nanomaterials" for the purposes of health and environment assessments, given the early evidence that they may pose health risks similar to particles less than 100nm in size that have to date been defined as "nano."

Transparency in safety assessment and product labeling is essential.

- All relevant data related to safety assessments and the methodologies used to obtain them must be placed in the public domain.
- All manufactured nano-ingredients must be clearly indicated on product labels to allow members of the public to make an informed choice about product use.
- The presence of nanomaterials must be disclosed to workers and other downstream users along the supply chain.

Public involvement in decision making is required.

- The public, including all affected stakeholder groups, must be involved in all aspects of decision making regarding nanotechnology in food and agriculture. This includes the development of regulatory regimes and labeling systems, and prioritization of public funding for food and agricultural research. People's right to avoid nanofoods must be recognized explicitly.

Support for sustainable food and farming is needed.

- The assessment of food and agricultural nanotechnology, in the context of wider societal needs for sustainable food and farming, must be incorporated into relevant decision-making processes.

What industry must do:

Food producers and retailers must respect people's right to healthy foods in which all ingredients have been proven safe. Food producers and retailers must stop selling nanofood, nanofood packaging, nanofood contact materials and nano-agrochemicals until:

- The public is involved in decision making.
- Nanotechnology-specific regulations are put in place to protect the public, workers and the environment from potential new hazards associated with nano-toxicity.
- All manufactured nano-ingredients are clearly indicated on product labels to allow members of the public to make an informed choice about product use.
- The presence of nanomaterials are disclosed to workers and other downstream users along the supply chain.
- Manufacturers work with regulators to ensure that their products have undergone appropriate safety testing, and provide the relevant data regarding the health and environmental safety of their product. No data, no market.
- All relevant data related to safety assessments, and the methodologies used to obtain them, are to be placed in the public domain.
- All food and agricultural products that include manufactured nanomaterials are clearly labeled to allow members of the public, workers and farmers to make an informed choice.

What concerned individuals and organizations can do:

Until we can move our government and companies to manage nanotechnology in a responsible and transparent manner, there are steps we can take to protect our health and the environment.

Avoiding nanofoods and supporting a sustainable, just food system:

- Avoid eating highly processed foods and eat more fresh food instead. Processed foods not only have higher environmental costs of production and lower nutritional value, they are also a big source of incidentally produced nanoparticles in foods.
- Avoid highly packaged foods — packaging is energy intensive and produces lots of waste and is often unnecessary. Let your local food outlets and the manufacturers of your favourite foods know that you want to see less food packaging.
- Choose food that is healthy for you and the environment, and that pays a fair wage to food producers. There are many simple steps we can all take to make food choices that are good for our health, good for the environment, and that support fair conditions for farmers.
- Make environmentally friendly food and farming choices — look out for the organic label at your supermarket or store.
- Support local food producers and small-scale retailers and buy directly from local farmers,

butchers and bakers. You could even consider joining a food co-operative or bulk-buying scheme.

- Support the right of communities to control local food trade, including deciding how food is grown, who can sell it and what can be imported.

Hold government and industry to account over nanofoods:

- Write to your local representatives and members of local, state and federal government, requesting their support for a moratorium on the use of all nanotechnology in the food sector. Demand that governments regulate and label food, food packaging and agricultural products that contain manufactured nanomaterials before allowing any further commercial sales.

- Ensure that food and agricultural manufacturers take seriously public concerns about nanofoods. Contact the manufacturers of foods you eat often and ask them about what steps they are taking to keep unsafe, untested nanomaterials out of the food they sell.

- Insist that governments and industry take seriously the risks of occupational exposure to nanomaterials for food and agricultural workers. If you are concerned about nano-exposure in your work place, talk with your colleagues or your union representative about opportunities for collective action to secure a safe workplace.

- Contact civil society organizations you think may be interested in taking action to ensure precautionary management of the use of nanotechnology in food and agriculture applications. Find out what environment, public health, farmers and civil liberties organizations in your neighborhood are doing to work toward alternative food systems that deliver positive environmental and social outcomes.

Visit our website to learn more about nanotechnology or to support our work for safe food, and a just, resilient and sustainable food system.

Friends of the Earth-United States
http://www.foe.org/projects/food-and-technology/nanotechnology

8. REFERENCES

1. Center for Food Safety (2007). Principles for the Oversight of Nanotechnologies and Nanomaterials, http://www.centerforfoodsafety.org/issues/682/nanotechnology/reports/961/principles-for-the-oversight-of-nanotechnologies-and-nanomaterials (accessed 9 May 2014)

2. Garnett M. and Kallinteri P. (2006). Nanomedicines and nanotoxicology: some physiological principles. Occupational Medicines 56:307-311.

3. Nature Nanotechnology (2010). Nanofood for Thought, http://www.nature.com/nnano/journal/v5/n2/pdf/nnano.2010.22.pdf (accessed 19 March 2014)

4. Garnett M. and Kallinteri P. (2006). Nanomedicines and nanotoxicology: some physiological principles. Occupational Medicines 56:307-311.

5. Hansen, T., Clermont, G., Alves, A., Eloy, R., Brochhausen, C., Boutrand, J., Gatti, A., Kirkpatrick, J. (2006). Biological tolerance of different materials in bulk and nanoparticulate form in a rat model: sarcoma development by nanoparticles. Journal of the Royal Society Interface 3:767–775

6. Des Rieux A., Fievez V., Garinot M,. Schneider Y.and Preat V. (2006). Nanoparticles as potential oral delivery systems of proteins and vaccines: a mechanistic approach. Journal of controlled release 116:1-27

7. Sanguansri P. and Augustin M. (2006). Nanoscale materials development – a food industry perspective. Trends in Food Science and Technology 17:547-556.

8. Mozafari, M., Flanagan, J., Matia-Merino, L., Awati, A., Omri, A., Suntres, Z., Singh, H. (2006). Recent trends in the lipid-based nanoencapsulation of antioxidants and their role in foods. Journal of the Science of Food and Agriculture 86:2038-2045;

9. Wang, B., Feng, W., Wang, M., Wang, T., Gu, Y., Zhu, M., Ouyang, H., Shi, J., Zhang, F., Zhao, Y., Chai, Z., Wang, H., Wang, J. (2007). "Acute toxicological impact of nano- and submicro-scaled zinc oxide powder on healthy adult mice". Journal of Nanoparticle Research DOI 10.1007/s11051-007-9245-3

10. Wang, B., Feng, W-Y., Wang, T.-C., Jia, G., Wang, M., Shi, J.-W., Zhang, F., Zhao, Y.-L., Chai, Z.-F. (2006). "Acute toxicity of nano- and micro-scale zinc powder in healthy adult mice". Toxicology Letters 161:115–123

11. Institute of Occupational Medicine for the Health and Safety Executive (2004). Nanoparticles: An occupational hygiene review. Available at http://www.hse.gov.uk

12. Yamawaki, H., Iwai, N. (2006). Mechanisms Underlying Nano-Sized Air-Pollution- Mediated Progression of Atherosclerosis Carbon Black Causes Cytotoxic Injury/Inflammation and Inhibits Cell Growth in Vascular Endothelial Cells. Circulation Journal 70: 129 –140

13. Nel A, Xia T, Li N (2006). "Toxic potential of materials at the nanolevel". Science Vol 311:622-627

14. The Royal Society and Royal Academy of Engineering (2004) Nanoscience and Nanotechnologies: Opportunities and Uncertainties. London: The Royal Society http://www.nanotec.org.uk/finalReport.htm

15. For examples of specific products, visit the Consumer Products Inventory hosted by the Woodrow Wilson Center for International Scholars' Project on Emerging nanotechnologies at: http://nanotechproject.org

16. P 5, Roco M (2001). "From vision to the implementation of the U.S. National Nanotechnology Initiative". Journal of Nanoparticle Research 3:5-11

17. P5-6, Roco M and Bainbridge W (Eds) (2002). Converging Technologies for Improving Human Performance: nanotechnology, biotechnology, information technology and cognitive science. NSF/DOC-sponsored report. Available at: http://www.wtec.org/ConvergingTechnologies/

18. Nanowerk News (2014). Antimicrobial edible films inhibit pathogens in meat, http://www.nanowerk.com/nanotechnology_news/newsid=35425.php (accessed 8 May 2014)

19. Schneider, A. (2010) Regulated or Not, Nano-Foods Coming to a Store Near You, http://www.aolnews.com/2010/03/24/regulated-or-not-nano-foods-coming-to-a-store-near-you (accessed 19 February 2014)

20. Chen, L., Remondetto, G., Subirade, M. (2006). Food protein-based materials as nutraceutical delivery systems. Trends in Food Science & Technology 17:272–283

21. The Environmental Magazine (2012). Eating Nano, http://www.emagazine.com/includes/print-article/magazine/9623/ (accessed 4 March 2014)

22. Gerloff K, Albrecht C, Boots AW, Förster I, Schins RPF: Cytotoxicity and oxidative DNA damage by nanoparticles in human intestinal Caco-2 cells. Nanotoxicology 3 (4): 355-364, 2009.

23. Dekker, K. et al., Knowledge gaps in risk assessment of nanosilica in food: evaluation of the dissolution and toxicity of different forms of silica. Nanotoxicology, June 2013; 7(4):367–377, 368

24. SRU (Sachverständigenrat für Umweltfragen) (2011). Vorsorgestrategien für Nanomaterialien, http://www.umweltrat.de/SharedDocs/Downloads/DE/02_Sondergutachten/2011_09_SG_Vorsorgestrategien%20f%C3%BCr%20Nanomaterialien.pdf?__blob=publicationFile (accessed 9 May 2014)

25. Correia Carreira, S. (2013) The toxicity, transport and uptake of nanoparticles in the in vitro BeWo b30 placental cell barrier model used within NanoTEST, Nanotoxicology, 1-14, http://informahealthcare.com/doi/pdf/10.3109/17435390.2013.833317

26. Scientific Committee on Emerging and Newly Identified Health Risks. Preliminary Opinion, Nanosilver: safety, health and environmental effects and role in antimicrobial resistance, December 2013, p 21. Online at: http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_039.pdf (accessed 13 March 2014)

27. NRDC vs. U.S. EPA and Heiq Materials AG (2013) http://cdn.ca9.uscourts.gov/datastore/opinions/2013/11/07/12-70268.pdf (accessed 14 April 2014)

28. Scientific Committee on Emerging and Newly Identified Health Risks. Preliminary Opinion, Nanosilver: safety, health and environmental effects and role in antimicrobial resistance, December 2013, p 21-22, 24. Online at: http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_039.pdf (accessed 13 March 2014)

29. BfR (Bundesinstitut für Risikobewertung) (2010). BfR rät von Nanosilber in Lebensmitteln und Produkten des täglichen Bedarfs ab, http://www.bfr.bund.de/cm/343/bfr_raet_von_nanosilber_in_lebensmitteln_und_produkten_des_taeglichen_bedarfs_ab.pdf (accessed 14 March 2014)

30. Correia Carreira, S. (2013) The toxicity, transport and uptake of nanoparticles in the in vitro BeWo b30 placental cell barrier model used within NanoTEST, Nanotoxicology, 1-14, http://informahealthcare.com/doi/pdf/10.3109/17435390.2013.833317

31. Browning, L.M. (2013) Silver Nanoparticles Incite Size- and Dose-Dependent Developmental Phenotypes and Nanotoxicity in Zebrafish Embryos, Chem. Res. Toxicol. 26(10):1503–1513.

32. Friends of the Earth U.S. (2011) Nano-silver: policy failure puts public health at risk, http://nano.foe.org.au/sites/default/files/Nano-silver_2011%20Aus%20v2%20web.pdf (accessed 28 March 2014)

33. ECHA, Justification document for the selection of a CoRAP substance – Titanium Dioxide, 2013

34. ChemEurope.com (2009). Nanoparticles used in common household items caused genetic damage in mice, http://www.chemeurope.com/en/news/109581/nanoparticles-used-in-common-household-items-caused-genetic-damage-in-mice.html (accessed 27 July 2012)

35. Ashwood P, et al. 2007. Fine particles that adsorb lipopolysaccharide via bridging calcium cations may mimic bacterial pathogenicity towards cells. Exp Biol Med 232(1):107-117

36. Donaldson K, et al. 1996. Free radical activity associated with the surface of particles: a unifying factor in determining biological activity? Toxicol Lett 88:293-298

37. Dunford R, Salinaro A, Cai L, Serpone N, Horikoshi S, Hidaka H, Knowland J. 1997. Chemical oxidation and DNA damage catalysed by inorganic sunscreen ingredients. FEBS Lett 418:87-90

38. Long T, Saleh N, Tilton R, Lowry G, Veronesi B. 2006. Titanium dioxide (P25) produces reactive oxygen species in immortalized brain microglia (BV2): Implications for nanoparticle neurotoxicity. Environ Sci Technol 40(14):4346-4352

39. Lucarelli M, Gatti A, Savarino G, Quattroni P, Martinelli L, Monari E, Boraschi D 2004. Innate defence functions of macrophages can be biased by nano-sized ceramic and metallic particles. Eur Cytok Net 15(4):339-346

40. Wang J, Zhou G, Chen C, Yu H, Wang T, Ma Y, Jia G, Gai Y, Li B, Sun J, Li Y, Jiao F, Zhano Y, Chai Z. 2007b. Acute toxicity and biodistribution of different sized titanium dioxide particles in mice after oral administration. Toxicol Lett 168(2):176-185

41. Wang J, Zhou G, Chen C, Yu H, Wang T, Ma Y, Jia G, Gai Y, Li B, Sun J, Li Y, Jiao F, Zhano Y, Chai Z. 2007b. Acute toxicity and biodistribution of different sized titanium dioxide particles in mice after oral administration. Toxicol Lett 168(2):176-185

42. BfR / UBA (Bundesinsitut für Risikobewertung und Umweltbundesamt) (2010). Beurteilung eines möglichen Krebsrisikos von Nanomaterialien und von aus Produkten freigesetzten Nanopartikeln, http://www.bfr.bund.de/cm/343/beurteilung_eines_moeglichen_krebsrisikos_von_nanomaterialien_und_von_aus_produkten_freigesetzten_nanopartikeln.pdf (accessed 3 July 2012)

43. LUBW (Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg) (2010). Nanomaterialien: Toxikologie/Ökotoxikologie, http://www.lubw.baden-wuerttemberg.de/servlet/is/62024/U10-S05-N10.pdf?command=downloadContent&filename=U10-S05-N10.pdf (accessed 25 July 2012)

44. Takeda, K. et al. (2009). Nanoparticles Transferred from Pregnant Mice to Their Offspring Can Damage the Genital and Cranial Nerve Systems, Journal of Health Science 55(1):95–102, http://jhs.pharm.or.jp/data/55%281%29/55_95.pdf

45. Weir, A. et al. (2012). Titanium dioxide nanoparticles in food and personal care products, Environmental Science and Technology 46:2242-2250.

46. Scientific Committee on Consumer Safety (2012). Opinion on zinc oxide (nano form), COLIPA S 76, pp. 30, 93, http://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_o_103.pdf

47. *Ibid* p. 96.

48. *Ibid*

49. aid Informationsdienst (2011). Nanotechnologien bei Lebensmitteln, http://www.aid.de/shop/pdf/0085_2011_nanoflyer_x000.pdf (accessed July 30.2012) Allied Biotech Europe GmbH (2012), http://www.altratene.com/dietary.php (accessed 22 July 2012)

50. BfR (Bundesinsitut für Risikobewertung) (2012). Nanosilver: Progress in analysis, gaps in toxicology and exposure, http://www.bfr.bund.de/de/presseinformation/2012/08/nanosilber__fortschritte_in_der_analytik__luecken_bei_toxikologie_und_exposition-128936.html (accessed 1 August 2012)

51. Plastemart.com: Nanotechnology can enhance food packaging, http://www.plastemart.com/upload/literature/Nanotechnology-enhance-improve-food%20packaging.asp (accessed 13 March 2014)

52. Safe Work Australia, Human Health Hazard Assessment and Classification of Carbon Nanotubes. Online at http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/human-health-hazard-assessment-and-classification-of-carbon-nanotubes. (accessed 13 March 2014)

53. Miller and Senjen, Out of the Laboratory and onto our Plates: nanotechnology in food and agriculture, Friends of the Earth United States, 2008

54. Woodrow Wilson International Centre for Scholars. A Hard Pill to Swallow: Barriers to Effective FDA Regulation of Nanotechnology-based Dietary Supplements. 2009. Online at http://www.nanotechproject.org/process/assets/files/7056/pen17_final.pdf (accessed 13 March 2014)

55. Franz R .2005. Migration modelling from food-contact plastics into foodstuffs as a new tool for consumer exposure estimation. Food Additives and Contaminants 22(10): 920–937

56. Das R, Selke S, Harte J. 2007. Development of electronic nose method for evaluation of HDPE flavour characteristics correlated with organoleptic testing. Packaging Technology and Science 20:125-136

57. IFST 2006. Information Statement: Nanotechnology. Institute of Food Science & Technology Trust Fund, London. Available at: http://www.ifst.org/uploadedfiles/cms/store/ATTACHMENTS/Nanotechnology.pdf (accessed 15 January 2008)

58. Ashwood P, Thompson R, Powell J. 2007. Fine particles that adsorb lipopolysaccharide via bridging calcium cations may mimic bacterial pathogenicity towards cells. Exp Biol Med 232(1):107-117 and Gatti A. 2004. Biocompatibility of micro- and nano-particles in the colon. Part II. Biomaterials 25:385-392 and Schneider J. 2007. Can microparticles contribute to inflammatory bowel disease: Innocuous or inflammatory? Exp Biol Med 232:1-2

59. Chen Z, Meng H, Xing G, Chen C, Zhao Y, Jia G, Wang T, Yuan H, Ye C, Zhao F, Chai Z, Zhu C, Fang X, Ma B, Wan L. (2006b) Acute toxicological effects of copper nanoparticles in vivo. Toxicol Lett 163:109-120

60. Desai M, Labhasetwar V, Amidon G, Levy R. (1996) Gastroinestinal uptake of microparticles: Effect of particle size. Pharm Res 13(12):1838-1845

61. Hillyer J, Albrecht R. (2001) Gastrointestinal persorption and tissue distribution of differently sized colloidal gold nanoparticles. J Pharm Sci 90(12):1927-1936

62. Wang B, et al. (2007a) Acute toxicological impact of nano- and submicro-scaled zinc oxide powder on healthy adult mice. J Nanopart Res 10(2):263-276

63. Wang J, et al. (2007b) Acute toxicity and biodistribution of different sized titanium dioxide particles in mice after oral administration. Toxicol Lett 168(2):176-185

64. Hazzard R, Hodges G, Scott J, McGuinness C, Carr E. (1996) Early intestinal microparticle uptake in the rat. J Anat 189:265-271

65. McMinn L, Hodges G, Carr K. (1996) Gastrointestinal uptake and translocation of microparticles in the streptozotocin-diabetic rat. J Anatom 189:553-559

66. Wang B, Feng W-Y, Wang T-C, Jia G, Wang M, Shi J-W, Zhang F, Zhao Y-L, Chai Z-F. (2006) Acute toxicity of nano- and micro-scale zinc powder in healthy adult mice. Toxicol Lett 161:115–123

67. Ballestri M, Baraldi A, Gatti A, Furci L, Bagni A, Loria P, Rapana R, Carulli N, Albertazzi A. (2001) Liver and kidney foreign bodies granulomatosis in a patient with malocclusion, bruxism, and worn dental prostheses. Gastroenterol 121(5):1234–8

68. Gatti A, Rivasi F. (2002) Biocompatibility of micro- and nanoparticles. Part I: in liver and kidney. Biomaterials 23:2381–2387

69. LUBW (Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg) (2010). Nanomaterialien: Toxikologie/Ökotoxikologie, http://www.lubw.baden-wuerttemberg.de/servlet/is/62024/U10-S05-N10.pdf?command=downloadContent&filename=U10-S05-N10.pdf (accessed 25 July 2012)

70. SRU (Sachverständigenrat für Umweltfragen) (2011). Vorsorgestrategien für Nanomaterialien, http://www.umweltrat.de/SharedDocs/Downloads/DE/02_Sondergutachten/2011_09_SG_Vorsorgestrategien%20f%C3%BCr%20Nanomaterialien.pdf?__blob=publicationFile (accessed 9 July 2012)

71. Spiegel online (2012). Nanopartikel verändern Eisenaufnahme im Darm, http://www.spiegel.de/wissenschaft/medizin/diskussion-um-gefahren-nanopartikel-veraendern-eisenaufnahme-im-darm-a-814794.html (accessed 15 July 2012).

72. Powell JJ, Faria N, Thomas-McKay E, Pele LC. (2010) Origin and fate of dietary nanoparticles and microparticles in the gastrointestinal tract. J Autoimmun 34:J226–J233; Powell JJ, Ainley CC, Harvey RSJ, Mason IM, Kendall MD, Sankey EA, et al. (1996) Characterisation of inorganic microparticles in pigment cells of human gut associated lymphoid tissue. Gut 38:390–95.

73. Ashwood P, Thompson R, Powell J. (2007) Fine particles that adsorb lipopolysaccharide via bridging calcium cations may mimic bacterial pathogenicity towards cells. Exp Biol Med 232(1):107-117

74. Gatti A, Tossini D, Gambarelli A. (2004) Investigation Of Trace Elements In Bread Through Environmental Scanning Electron Microscope And Energy Dispersive System. 2nd International IUPAC Symposium, Brussels, October 2004

75. Lomer M, Harvey R, Evans S, Thompson R, Powell P. (2001) Efficacy and tolerability of a low microparticle diet in a double blind, randomized, pilot study in Crohn's disease. Eur J Gastroenterol Hepatol 13:101-106.

76. Lucarelli M, Gatti A, Savarino G, Quattroni P, Martinelli L, Monari E, Boraschi D. (2004) Innate defence functions of macrophages can be biased by nano-sized ceramic and metallic particles. Eur Cytok Net 15(4):339-346

77. SRU (Sachverständigenrat für Umweltfragen) (2011). Vorsorgestrategien für Nanomaterialien, http://www.umweltrat.de/SharedDocs/Downloads/DE/02_Sondergutachten/2011_09_SG_Vorsorgestrategien%20f%C3%BCr%20Nanomaterialien.pdf?__blob=publicationFile (accessed 9 July 2012)

78. EFSA (2009) The Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety, http://www.efsa.europa.eu/en/efsajournal/doc/958.pdf (accessed 10 March 2014)

79. Scientific Committee on Consumer Safety (2012) Opinion on zinc oxide (nano form), COLIPA S 76, p. 96, http://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_o_103.pdf; Scientific Committee on Consumer Safety (2013) Opinion on titanium dioxide (nano form), http://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_o_136.pdf (both accessed 13 March 2014)

80. Oberdörster G, Maynard A, Donaldson K, Castranova V, Fitzpatrick J, Ausman K, Carter J, Karn B, Kreyling W, Lai D, Olin S, Monteiro-Riviere N, Warheit D, Yang H. (2005) Principles for characterising the potential human health effects from exposure to nanomaterials: elements of a screening strategy. Particle Fibre Toxicol 2:8

81. Safe Work Australia, Human Health Hazard Assessment and Classification of Carbon Nanotubes, http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/human-health-hazard-assessment-and-classification-of-carbon-nanotubes. (accessed 13 March 2014)

82. The Environmental Magazine (2012). Eating Nano, http://www.emagazine.com/includes/print-article/magazine/9623/ (accessed 4 March 2014)

83. Helmut Keiser (2003). Nanotechnology in Food and Food Processing Worldwide, http://www.hkc22.com/nanofood.html (accessed 14 March 2014)

84. *Ibid*

85. Innovest (2006). Nanotechnology: Non-traditional Methods for Valuation of Nanotechnology Producers. Innovest, Strategic Value Advisers

86. Wolfe J. (2005). Safer and guilt-free nano foods. Forbes.com U.S. 10.08.05. http://www.forbes.com/investmentnewsletters/2005/08/09/nanotechnology-kraft-hershey-cz_jw_0810soapbox_inl.html (accessed 12 March 2014)

87. Renton A. (2006). Welcome to the world of nano foods. Guardian Unlimited UK 13.12.06. Available at http://observer.guardian.co.uk/foodmonthly/futureoffood/story/0,,1971266,00.html#article_continue

88. Consumer Products Inventory hosted by the Woodrow Wilson Center for International Scholars' Project on Emerging nanotechnologies (2014). http://www.nanotechproject.org/cpi/ (accessed 19 February 2014); Weir A., Westerhoff P., Fabricius L., von Goetz N. (2013) Titanium Dioxide Nanoparticles in Food and Personal Care Products. Environ. Sci. Tech. Feb. 8 2013

89. U.S. Food and Drug Administration: http://www.fda.gov/ScienceResearch/SpecialTopics/Nanotechnology/default.htm (Accessed 18 February 2014)

90. U.S. Food and Drug Administration: http://www.fda.gov/ScienceResearch/SpecialTopics/Nanotechnology/default.htm (Accessed 18 February 2014)

91. Franz R .(2005), Migration modelling from food-contact plastics into foodstuffs as a new tool for consumer exposure estimation. Food Additives and Contaminants 22(10): 920–937.

92. Das R., Selke S., Harte J. (2007). Development of electronic nose method for evaluation of HDPE flavour characteristics correlated with organoleptic testing. Packaging Technology and Science 20:125-136.

93. Progressive Grocer (2013). Geisslers Adopts OnVu Meat Labeling, http://www.progressivegrocer.com/top-stories/headlines/meat-seafood/id34759/geisslers-adopts-onvu-meat-labeling/ (accessed 13 March 2014)

94. OnVu (2007). OnVu the label that makes freshness visible, http://www.youtube.com/watch?v=cvpcgNqUImw (accessed 8 March 2014)

95. ToddlerHealth (2013). http://www.toddlerhealth.net/ (accessed 20 February 2014)

96. Solace Nutrition (2014). NanoVM General Info, http://www.solacenutrition.com/products/nanovm/nanovm.html (accessed 20 February 2014)

97. Consumer Products Inventory hosted by the Woodrow Wilson Center for International Scholars' Project on Emerging nanotechnologies (2014). http://www.nanotechproject.org/cpi/ (accessed 19 February 2014)

98. Weir A., Westerhoff P., Fabricius L., von Goetz N. (2013) Titanium Dioxide Nanoparticles in Food and Personal Care Products. Environ. Sci. Tech. Feb. 8 2013

99. Soutter, W. (2012) Nanotechnology in Functional Foods, http://www.azonano.com/article.aspx?ArticleID=3065#Introduction

100. FoodSafety magazine 2012. Potential Use of Edible nanoscale Coatings for Meat. Online at: http://www.foodsafetymag-digital.com/foodsafetymag/20120607?pg=4#pg54 (accessed 10 March 2014)

Fraunhofer (2010). Nano-Anwendungen in der Lebensverpackung, http://www.nanowissen.bayern.de/docs/franz_fraunhoferivv.pdf und http://www.ube.de/index.html (accessed 8 August 2012)

101. Schneider, A. (2010) Regulated or Not, Nano-Foods Coming to a Store Near You, http://www.aolnews.com/2010/03/24/regulated-or-not-nano-foods-coming-to-a-store-near-you (accessed 19 February 2014)

102. Schneider, A. (2010) Regulated or Not, Nano-Foods Coming to a Store Near You, http://www.aolnews.com/2010/03/24/regulated-or-not-nano-foods-coming-to-a-store-near-you (accessed 19 February 2014)

103. Tran C., Donaldson K., Stones V., Fernandez T., Ford A., Christofi N., Ayres J., Steiner M., Hurley J., Aitken R., Seaton A. (2005). A scoping study to identify hazard data needs for addressing the risks presented by nanoparticles and nanotubes. Research Report. Institute of Occupational Medicine, Edinburgh

104. Luo, J. (2007). "Toxicity and bioaccumulation of nanomaterial in aquatic species". Journal of the United States Stockholm Junior Water Prize. doi: 10.2175/SJWP(2007)1:01

105. Moore M. (2006). Do nanoparticles present ecotoxicological risks for the health of the aquatic environment. Environment International 32: 967-976. p968

106. Senjen R. (2007). Nanosilver – a threat to soil, water and human health? Friends of the Earth Australia March 2007. Available at: http://nano.foe.org.au/node/189

107. Fortner J, Lyon D, Sayes C, Boyd A, Falkner J, Hotze E, Alemany L, Tao Y, Guo W, Ausman K, Colvin V, Hughes J (2005).C60 in Water: Nanocrystal Formation and Microbial Response. Environmental Science and Toxicology 39(11), 4307-4316

108. Zhang, L., Jiang, Y., Ding, Y., Povey, M., York, D. (2007). "Investigation into the antibacterial behaviour of suspensions of ZnO nanoparticles (ZnO nanofluids)". Journal of Nanoparticle Research 9:479–489

109. Kang, S., Pinault, M., Pfefferle, L., Elimelech, M. (2007). "Single-Walled Carbon Nanotubes Exhibit Strong Antimicrobial Activity". Langmuir 23: 8670-8673

110. Throback I.N., Johansson M., Rosenquist M., Pell M., Hansson M., Hallin S. (2007). Silver (Ag(+)) reduces denitrification and induces enrichment of novel nirK genotypes in soil. FEMS Microbiol Lett. 2007 Jan 23

111. Oberdörster G., Oberdörster E. and Oberdörster J. (2005). Nanotoxicology: an emerging discipline from studies of ultrafine particles. Environmental Health Perspectives 113(7):823-839.

112. Nanologue.net (2005) Appendix to the Nanologue Background Paper on selected nanotechnology applications and their ethical, legal and social implications. Available at: http://www.nanologue.net/custom/user/Downloads/NanologueBackgroundPaperAppendix.pdf,

113. Melhus, A (2007). Silver threatens the use of antibiotics. Unpublished manuscript, received by email 30/1/07

114. Lovern, B., Klaper, R. (2006). Daphnia magna mortality when exposed to titanium dioxide and fullerene (c60) nanoparticles. Environmental Toxicology and Chemistry 25(4):1132-1137

115. Hund-Rinke K and Simon M (2006). Ecotoxic effect of photocatalytic active nanoparticles (TiO2) on algae and daphnids. Environmental Science and Pollution Research 13(4):225-232

116. Luo, J. (2007). Toxicity and bioaccumulation of nanomaterial in aquatic species. Journal of the United States Stockholm Junior Water Prize. doi: 10.2175/SJWP(2007)1:01

117. Oberdörster E (2004). Manufactured nanomaterials (fullerenes, C60) induce oxidative stress in the brain of juvenile largemouth bass. Environmental Health Perspectives 112:1058-1062

118. Zhu, S., Oberdorster, E., Haasch, M. (2006). Toxicity of an engineered nanoparticle (fullerene, C60) in two aquatic species, Daphnia and fathead minnow. Marine Environmental Research 62:S5–S9.

119. Templeton, P., Ferguson, P., Washburn, K., Scrivens, W., Chandler, G. (2006). Life-Cycle Effects of Single-Walled Carbon Nanotubes (SWNTs) on an Estuarine Meiobenthic Copepod. Environmental Science and Technology 40:7387-7393

120. Cheng, J., Flahaut, E., Cheng, S. (2007). Effect of carbon nanotubes on developing zebrafish (Danio rerio) embryos. Environmental Toxicology and Chemistry 26(4):708-716

121. Lovern, B., Klaper, R. (2006). Daphnia magna mortality when exposed to titanium dioxide and fullerene (c60) nanoparticles. Environmental Toxicology and Chemistry 25(4):1132-1137

122. Oberdorster E (2004b) Toxicity of nC60 fullerenes to two aquatic species: Daphnia and largemouth bass [Abstract]. In: 227th American Chemical Society National Meeting, Anaheim, CA, March 28-April 1, 2004. Washington DC: American Chemical Society I&EC 21. Available at: http://oasys2.confex.com/acs/227nm/techprogram/P719002.HTM

123. Lovern, S., Strickler, J., Klaper, R. (2007). Behavioural and physiological changes in Daphnia magna when exposed to nanoparticle suspensions (Titanium dioxide, Nano C-60 and C60HxC70Hx). Environmental Science and Technology 41:4465-4470

124. Fortner J, Lyon D, Sayes C, Boyd A, Falkner J, Hotze E, Alemany L, Tao Y, Guo W, Ausman K, Colvin V, Hughes J (2005). C60 in Water: Nanocrystal Formation and Microbial Response. Environmental Science and Toxicology 39(11); 4307-4316

125. Yang L., Watts D.J.(2005). Particle surface characteristics may play an important role in phytotoxicity of alumina nanoparticles Toxicol Lett. Volume 158(2):122-32.

126. RS/RAE (Royal Society / Royal Academy of Engineering) (2004) Nanoscience and nanotechnologies: opportunities and uncertainties. Online at: http://www.nanotec.org.uk/finalReport.htm, Section 5.7: paragraph 63 (accessed 5 July 2012)

127. EU Commission (2012) (2). Chemicals Thematic studies for Review of REACH 2012. Review of EU legislation (REACH) concerning nanotechnology. Online at: http://ec.europa.eu/enterprise/sectors/chemicals/documents/reach/review2012/nanotechnology_en.htm (accessed 21 November 2012)

128. Sweet et al. 2011 in Scientific Committee on Emerging and Newly Identified Health Risks. Preliminary Opinion, Nanosilver: safety, health and environmental effects and role in antimicrobial resistance, December 2013, p 16. Online at: http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_039.pdf (accessed 13 March 2014)

129. Bondarenko O, Juganson K, Ivask A, Kasemets K, Mortimer M, Kahru A. Toxicity of Ag, CuO and ZnO nanoparticles to selected environmentally relevant test organisms and mammalian cells in vitro: a critical review. Archives of Toxicology. 2013;87(7):1181-200.

130. Federici G, Shaw B, Handy R. 2007. Toxicity of titanium dioxide nanoparticles to rainbow trout (Oncorhynchus mykiss): Gill injury, oxidative stress, and other physiological effects. Aquatic Toxicol 84(4):415-430

131. Hund-Rinke K, Simon M. 2006. Ecotoxic effect of photocatalytic active nanoparticles (TiO2) on algae and daphnids. Environ Sci Poll Res 13(4):225-232

132. Lovern B, Klaper R. 2006. Daphnia magna mortality when exposed to titanium dioxide and fullerene (c60) nanoparticles. Environ Toxicol Chem 25(4):1132-1137

133. http://link.springer.com/article/10.1007%2Fs11051-013-1692-4#page-1

134. Ruitenberg, R. (2013) Earthworm Health Hurt by Nanoparticles in Soil in Alterra Study, Bloomberg. Online at: www.bloomberg.com/news/2013-01-29/earthworm-health-hurt-by-nanoparticles-in-soil-in-alterra-study.html

135. Unrine, J.M. et al. (2013) Trophic transfer of Au nanoparticles from soil along a simulated terrestrial food chain, Environ Sci Technol., 46(17):9753-9760

136. Priester, J.H. (2012) Soybean susceptibility to manufactured nanomaterials with evidence for food quality and soil fertility interruption, PNAS, 109(37): 14734–14735

137. Unrine, J.M. et al. (2013) Trophic transfer of Au nanoparticles from soil along a simulated terrestrial food chain, Environ Sci Technol., 46(17):9753-9760)

138. Ruitenberg, R. (2013) Earthworm Health Hurt by Nanoparticles in Soil in Alterra Study, Bloomberg, www.bloomberg.com)/news/2013-01-29/earthworm-health-hurt-by-nanoparticles-in-soil-in-alterra-study.html

139. Colman, B.P. et al. (2013). Low Concentrations of Silver Nanoparticles in Biosolids Cause Adverse Ecosystem Responses under Realistic Field Scenario, PLOS ONE, 8(2):1-10)

140. Melhus A. 2007. Silver threatens the use of antibiotics. Unpublished manuscript, received by email 30 January 2007

141. Colman, B.P. et al. (2013); Priester, J.H. (2012); Hernandez-Viezcas, J.A. (2013) In Situ Synchrotron X-ray Fluorescence Mapping and Speciation of CeO2 and ZnO Nanoparticles in Soil Cultivated Soybean (Glycine max), ACS Nano, 7 (2):1415–1423

142. Hanson, S.F. et al. (2013) Nanotechnology – early lessons from early warnings, from Late lessons from early warnings: science, precaution, innovation, EEA Report No 1/2013, Ch 22, p 542

143. Kah, M., Nanopesticides: State of Knowledge, Environmental Fate, and Exposure Modeling. Critical Reviews in Environmental Science and Technology. Volume 43, Issue 16, 2013

144. Miller, G. & Senjen, R. (2008) Out of the Laboratory and onto our Plates: nanotechnology in food and agriculture, Friends of the Earth United States.

145. ETC Group. 2004. Down on the Farm. Available at: http://www.etcgroup.org (accessed 17 January 2008)

146. Scrinis G and Lyons K. 2007. The emerging nano-corporate paradigm: Nanotechnology and the transformation of nature, food and agri-food systems. Internat J Sociol Agric and Food. 15(2). Available at: http://www.csafe.org.nz/ (accessed 2 March 2008)

147. Relyea, R., Hoverman, J. (2006). "Assessing the ecology in ecotoxicology: a review and synthesis in freshwater systems". Ecology Letters 9: 1157–1171

148. Hanazato, T. (2001). "Pesticide effects on freshwater zooplankton: An ecological perspective". Environmental Pollution 112:1-10

149. Davidson, C., Knapp, A. (2007). "Multiple stressors and amphibian declines: Dual impacts of pesticides and fish on yellow-legged frogs". Ecological Applications 17 (2): 587-597

150. Beane Freeman, L., Bonner, M., Blair, A., Hoppin, J., Sandler, D., Lubin, J., Dosemeci, M., Lynch, C., Knott, C., Alavanja, M. (2005). "Cancer Incidence among Male Pesticide Applicators in the Agricultural Health Study Cohort Exposed to Diazinon". American Journal of Epidemiology 162(11): 1070-1079

151. van Balen, E., Font, R., Cavallé, N., Font, L., Garcia-Villanueva, M., Benavente, Y., Brennan, P., de Sanjose, S. (2006). "Exposure to non-arsenic pesticides is associated with lymphoma among farmers in Spain". Occupational and Environmental Medicine;63:663-668

152. Petrelli, G. , Figà-Talamanca, I., Tropeano, R., Tangucci, M., Cini, C., Aquilani, S., Gasperini, L., Meli, P. (2000). Reproductive male-mediated risk: Spontaneous abortion among wives of pesticide applicators. European Journal of Epidemiology 16: 391-393,

153. United States Environmental Protection Agency (2007). "U.S. Environmental Protection Agency Nanotechnology White Paper". Science Policy Council, U.S. Environmental Protection Agency, Washington D.C

154. Mach R (2004). "Nanoscale Particle Treatment of Groundwater. Federal Remedial Technology Roundtable: Naval Facilities Engineering Command". Available http://www.frtr.gov/pdf/meetings/l--mach_09jun04.pdf

155. Oberdörster G, Oberdörster E and Oberdörster J (2005). "Nanotoxicology: an emerging discipline from studies of ultrafine particles". Environmental Health Perspectives 113(7):823-839

156. See discussions in: United States Environmental Protection Agency (2007). "U.S. Environmental Protection Agency Nanotechnology White Paper". Science Policy Council, U.S. Environmental Protection Agency, Washington D.C.; Oberdörster G, Oberdörster E and Oberdörster J (2005). "Nanotoxicology: an emerging discipline from studies of ultrafine particles"; Environmental Health Perspectives 113(7):823-839 and Tran C, Donaldson K, Stones V, Fernandez T, Ford A, Christofi N, Ayres J, Steiner M, Hurley J, Aitken R, Seaton A (2005). A scoping study to identify hazard data needs for addressing the risks presented by nanoparticles and nanotubes. Research Report. Institute of Occupational Medicine, Edinburgh

157. Recommendation 5(ii), The Royal Society and The Royal Academy of Engineering, UK (2004). Nanoscience and nanotechnologies. Available at http://www.royalsoc.ac.uk/

158. Ervin, D., Welsh, R. (2003). "Environmental effects of genetically modified crops: differentiated risk assessment and management". Chapter 2a in J. Wesseler (Ed) "Environmental costs and benefits of transgenic crops in Europe: Implications for research, production, and consumption. Kluwer Academic Publishers, Dordrecht, The Netherlands

159. Friends of the Earth International (2007). Who benefits from GM crops? An analysis of the global performance of GM crops (1996-2006). Executive summary January 2007. FoEI, Amsterdam. Available at: http://www.foei.org

160. Batie, S. (2003). "The environmental impacts of genetically modified plants: Challenges to decision making". American Journal of Agricultural Economics 85(5):1107-1111

161. Ervin, D., Welsh, R. (2003). "Environmental effects of genetically modified crops: differentiated risk assessment and management". Chapter 2a in J. Wesseler (Ed) "Environmental costs and benefits of transgenic crops in Europe: Implications for research, production, and consumption. Kluwer Academic Publishers, Dordrecht, The Netherlands

162. ETC Group (2007). "Extreme genetic engineering: An introduction to synthetic biology". Available at: http://www.etcgroup.org/upload/publication/602/01/synbioreportweb.pdf

163. Friends of the Earth International (2007). Who benefits from GM crops? An analysis of the global performance of GM crops (1996-2006). Executive summary January 2007. FoEI, Amsterdam. Available at: http://www.foei.org

164. Tucker, J., Zilinskas, R. (2006). "The promise and the peril of synthetic biology". The New Atlantis 12: 25-45

165. United Nations Conference on Trade and Development (2013). Wake up before it is too late: Make agriculture truly sustainable now for food security in a changing climate, http://unctad.org/en/PublicationsLibrary/ditcted2012d3_en.pdf (accessed 24 February 2014)

166. *Ibid*

167. Institute for Agriculture and Trade Policy (2013). Nanomaterials in Soil: Our Future Food Chain?, http://www.iatp.org/files/2013_04_23_Nanotech_SS.pdf (accessed 9 May 2014)

168. Murray, D. (2005). “Oil and food: A new security challenge”. Asia Times Online June 3 2005. Available at: http://www.atimes.com/atimes/Global_Economy/GF03Dj01.html Accessed 21.09.07

169. Murray, D. (2005). “Oil and food: A new security challenge”. Asia Times Online June 3 2005. Available at: http://www.atimes.com/atimes/Global_Economy/GF03Dj01.html Accessed 21.09.07

170. Center for Food Safety (2007). Principles for the Oversight of Nanotechnologies and Nanomaterials, http://www.centerforfoodsafety.org/issues/682/nanotechnology/reports/961/principles-for-the-oversight-of-nanotechnologiesand-nanomaterials (accessed 9 May 2014)

171. *Ibid*

172. Congressional Research Service (2013). The National Nanotechnology Initiative: Overview, Reauthorization, and Appropriations Issues, p.41. http://www.fas.org/sgp/crs/misc/RL34401.pdf (accessed 7 May 2014)

173. Smithers, Rebecca (2008) Soil Association bans nanoparticles from organic products (The Guardian) http://www.theguardian.com/environment/2008/jan/15/organics.nanotechnology (accessed 7 May 2014)

174. Biological Farmers of Australia (2012). Nanotechnology prohibited from Australian Certified Organic beauty products, (Fatcow.com.au), p. 5, http://www.bfa.com.au/Portals/0/ACOS_2013.pdf (accessed 7 May 2014)

175. The Organic & Non-GMO Report (2010) Volume 10 Issue 5 (Evergreen Publishing), p. 18, http://www.non-gmoreport.com/ArchivesTwo/org&nongmo_may10.pdf (accessed 7 May 2014)

176. Davies J. 2007. EPA and Nanotechnology: Oversight for the 21st century. Project on Emerging Nanotechnologies 9 May 2007, Washington DC. Available at http://www.nanotechproject.org. Page 25

177. Institute for Agriculture and Trade Policy (2013). Nanomaterials in Soil: Our Future Food Chain?, http://www.iatp.org/files/2013_04_23_Nanotech_SS.pdf (accessed 9 May 2014) from U.S. General Accountability Office, “Nanomaterials Are Widely Used in Commerce, but EPA Faces Challenges in Regulating Risk,” GAO-10-549, May 2010, 33. Available at http://www.gao.gov/assets/310/304648.pdf.

178. *Ibid*

179. EFSA 2008. Inability to assess the safety of a silver hydrosol added for nutritional purposes as a source of silver in food supplements and the bioavailability of silver from this source based on the supporting dossier. Online at: http://www.efsa.europa.eu/de/efsajournal/doc/884.pdf (accessed 10 March 2014)

180. Hanson, S.F. et al. (2013) Nanotechnology – early lessons from early warnings, from Late lessons from early warnings: science, precaution, innovation, EEA Report No 1/2013, Ch 22

181. RCEP (Royal Commission on Environmental Pollution) (2008) Novel Materials in the Environment: The case of nanotechnolgy. Online at: http://nanotech.law.asu.edu/Documents/2009/07/Michael%20Vincent%20Royal%20Commission%20on%20Enviro%20Pollution%20%282008%29,%20Novel%20Ma_169_2476.pdf (accessed 10 March 2014)

182. NRC (2013). Research Progress on Environmental, Health, and Safety Aspects of Engineered Nanomaterials, http://www.nap.edu/catalog.php?record_id=18475 (accessed 27 March 2014)

183. SRU (Sachverständigenrat für Umweltfragen) (2011). Vorsorgestrategien für Nanomaterialien, http://www.umweltrat.de/SharedDocs/Downloads/DE/02_Sondergutachten/2011_09_SG_Vorsorgestrategien%20f%C3%BCr%20Nanomaterialien.pdf?__blob=publicationFile (accessed 19 July 2012)

184. NRC (2013). Research Progress on Environmental, Health, and Safety Aspects of Engineered Nanomaterials, http://www.nap.edu/catalog.php?record_id=18475 (accessed 27 March 2014)

185. *Ibid*

186. *Ibid*