Discussion paper on the use of nanotechnologies in organic production

This discussion paper was prepared at FiBL Switzerland. It constitutes a first pass at this very complex subject and makes no claims of being complete. Please send suggestions and comments to bernhard.speiser@fibl.org.

1 Introduction and definition

The term "nanotechnology" refers to the technical process of manufacturing or selectively altering material structures with a circumference of under 100 nm (nanometre = one billionth of a metre). But it also covers all applications and products that employ such material structures to take advantage of their special physical and chemical properties. This is less a technology than an umbrella term for a diverse array of applications [1].

Particles on the nanoscale can have natural (e.g. volcanic eruptions, fires) or artificial origins (i.e. made chemically/physically). Production processes that work with very small particles (e.g. tires with amorphous carbon or coatings for packaging) have been around for a long time. What is new is the systematic use and selective engineering of nanoparticles. There are different chemical/physical manufacturing processes: lithography, chemical processing in solutions (e.g. sol-gel method), processing in plasma, processing via self-organized growth on surfaces or with templates, processing by using targeted nucleation of molecules from the gas phase (aerosol process).

In the nano dimensions the chemical and physical properties of substances and materials can change radically. Nanoparticles commonly have different properties than the starting material they are made of. They can take on other mechanical, optical, magnetic or electrical features, and be more reactive and mobile than larger particles of the same substance. The substances most commonly used to produce nanomaterials are gold, silver, carbon and silicates[2].

The question for organic production is in which segments would it be possible to utilize nanotechnology or substances in nanoparticle form in near future and how should such a potential use be assessed.

2 Laws, regulations, action plans

Currently, there are no national or international regulations, definitions, licensing or declaration requirements. However, there is action on national and international levels regarding the regulation and standardization of nanotechnology. Notable are the EU's action plan, the activities of the OECD, the EMEA (European Agency for the Evaluation of Medical Products) and the FDA (United States Food and Drug Administration).

The Swiss Federal Office for the Environment (BAFU) and Federal Office of Public Health (BAG) are currently primarily relying on industry to act responsibly on its own and they have prepared a 2006–2009 nanotechnology action plan[3]. This action plan addresses different areas requiring action: creating an overview of the use of nanoparticles in Switzerland and the development of exposure scenarios, dialogue with stakeholder representatives, establishing a scientific basis for hazard and risk assessment, generating uniform definitions, measuring techniques and validated testing guidelines for hazard and risk assessment within the framework of the OECD, EU and ISO, adapting legislation if necessary, measures for protection of workers, etc.

[1] Factsheet Nanotechnologie [Nanotechnology fact sheet]. www.bag.admin.ch. 6.9.2006

[2] Swiss Re (2004). Nanotechnologie. Kleine Teile - grosse Zukunft? [Nanotechnology. Tiny particles, huge future?] Zurich, Swiss Reinsurance company. Author: Annabelle Hett. Series: Risk Perception.

[3] Nanotechnology action plan. http://www.bafu.admin.ch/chemikalien/01389/01393/01394/index.html?lang=de

TA-Swiss (Centre for Technology Assessment) held a public hearing ("publifocus") on nanotechnology in the autumn of 2006[4]. The hearing showed that citizens basically have a positive attitude toward this new technology, but the level of knowledge is low. At the forefront of the discussion of possible risks were products and applications (food, cosmetics, etc) sold to the public and issues regarding declaration.

3 Applications in the agricultural and food sectors

Several examples (list not conclusive) of nanoproducts in the agricultural and food sectors that are being developed or are already on the market are listed in Table 1. They are divided into seven groups of applications:

Group A: Additions of nanoparticles to food and animal feed. This sector is strictly regulated for organic production and is very unlikely for organic products.

Group B: Auxiliary substances in nanoparticle form such as organic pesticides with nanoparticle active substances, fertilizer or cleansers. There are both clear rules ("no chemical-synthetic substances") for assessing these substances and an assessment scheme based on which individual products can be assessed.

Group C: Medicines for veterinary use make up a special sector with its own regulations.

Groups D, E and F: Processing technologies and techniques that are not fundamentally different in the organic sector, e.g. surfaces, packaging, filters. For these applications there are principles and criteria that are somewhat different for organic production (e.g. the most environmentally friendly packaging should be chosen, low-impact processing), the technologies are judged on a case-by-case basis.

Table 1: Potential applications for nanotechnologies in the agricultural and food sectors, and their opportunities and risks.

Potential applications	New properties/opportunities	Risks for organic systems
A Additions of substances in the form of nanoparticles to food and animal feed		
Colourings, flavours and vitamins in nanocapsules	Dissolve better in beverages	Directly absorbed by the body, effect unknown!
Coating the surface of chocolate with a very thin layer of titanium dioxide	Chocolate does not melt as fast in hands, fingers stay clean	Directly absorbed by the body, effect unknown!
B Auxiliary substances		
Active substances in nanoparticle form	More soluble, more stable, more effective, systemic effect?	Systemic displacement/accumulation Greater toxicity for non-target organisms and humans?
Pesticides in microcapsules	Substance is released systematically under certain conditions, e.g. moisture, pH	Longer availability in the environment. Greater toxicity for non-target organisms and humans? Systemic displacement/accumulation
Cleansers	Efficient use of materials	???
Fertilizers	Less fertilizer needed due to selective application	Greater mobility?

[4] Nanotechnologien in der Schweiz: Herausforderungen erkannt. Bericht zum Dialogverfahren publifocus Nanotechnologien und ihre Bedeutung für Gesundheit und Umwelt [Nanotechnologies in Switzerland. Challenges recognized. Report on the "Nanotechnology, Health and the Environment" *publifocus* dialogue process]. http://www.ta-swiss.ch/a/nano_pfna/2006_TAP8_Nanotechnologien_d.pdf

Table 1, continued.

Potential applications	New properties/opportunities	Risks for organic systems
C Medicines		
(Veterinary) medicines	Medicines with nanoparticles can be targeted more precisely	Side effects on animal health Systemic displacement/accumulation in meat, milk, eggs?
D Packaging		
Plastic films and containers with integrated nanoparticles made from clay, silicon dioxide, zinc oxide, titanium dioxide	More tear-proof, more shock-resistant, less permeable to water vapour, gases and UV radiation; lighter, heat resistant; food keeps longer	Nanoparticles rub off? Nanoparticles in food?
Plastics with coating of silver nanoparticles	Antimicrobial, reduces germ formation, food keeps longer	Nanoparticles pass into food?
Nano coating inside beer bottles made out of PET and other materials	Less leaking of carbon dioxide, increases shelf life	Nanoparticles pass into food?
Biopolymers with integrated nanoparticles	More stable than other biopolymers, compostable	What happens during composting?
E Surface treatments		
Coating surfaces (glass, metal, ceramics, varnish) with layer of nanoparticles, e.g. titanium dioxide	Water and dirt-repellent, self-cleaning, scratchproof, rustproof	How long does the coating stay on? Rub-off? Nanoparticles pass into foods?
Silver nano layer on the inside of refrigerators	Antimicrobial, combats bacteria and fungi	Pass into food?
F New techniques for processing		
Nanofilters	Fewer resources consumed, more efficient	

4 Potential and risks

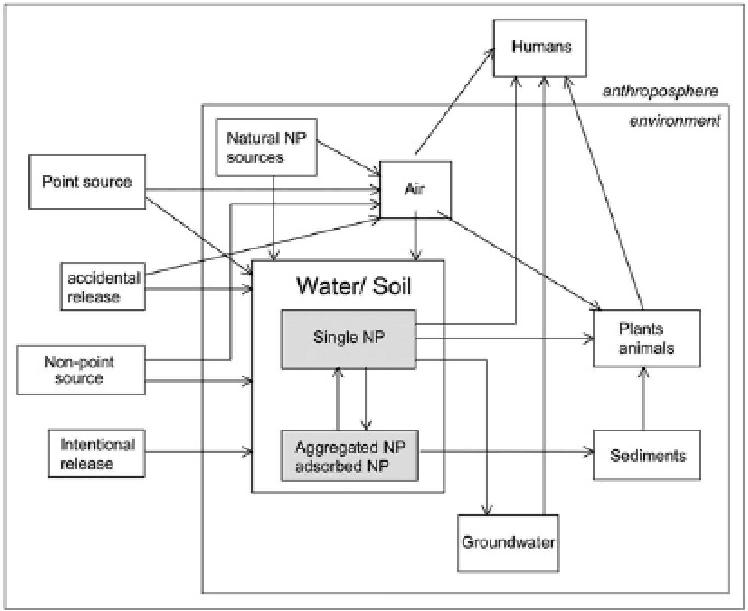
Potential

Many experts consider nanotechnology to be an industrial revolution which has great potential both for technological progress and for the environment and people. Nanotechnology is already being used in many sectors and a great deal of research is being done on it: mainly in all raw materials and substances sectors, in medicine, food technology, chemistry, electronics, computer technology, combustion technology, fuel cells, solar technology, and many more. Around the world there are already several hundred products on the market, but due to a lack of regulation and definition it is impossible to know exactly which products are involved. These opportunities include, for example, the potential for improved substance properties, greater energy efficiency, waste water treatment, biosensors, or using fewer raw materials. In the food sector nano-sealed surfaces could result in less detergent being used, the shelf life of foods could be extended by better packaging or antimicrobial surfaces, resources (energy, water) could be conserved by new technologies such as new filters, packaging could involve less material due to more impervious coatings or more stable biodegradable packaging, etc.

In the agricultural sector pesticides with active substances in nanoparticle form or in microcapsules are conceivable, which can be used selectively and can be more effective, as well as active pharmaceutical ingredients for the veterinary sector. The risks of and opportunities for the individual example applications are listed in Table 1.

Risks

Few data are available regarding the toxicology, release and environmental behaviour and safety of nanoparticles[5]. At this point there is no question of there being a conclusive risk assessment of nanoparticles since both the scientific and methodological bases are lacking. On national and international levels there are a number of research programmes working on clarifying some of the unanswered questions. Below is a summary of the most significant information gleaned from the few studies completed to date, keeping in mind that there is still a great deal that is not known[6].



Risks to the environment: Whether and how many nanoparticles get into the environment and how they behave (see Fig. 1) needs to be studied[7]. A new assessment needs to be done for each type of nanoparticle, and, depending on the situation, even for every application. However, the basic information required to do this is largely still lacking[5].

Fig. 1. Possible pathways from the anthroposphere into the environment and migration routes of nanoparticles (from Nowack and Bucheli 2007).

In principle, when free nanoparticles get into the environment adverse effects are possible. Nanoparticles could be more mobile than other contaminants in the environment or could bind to other contaminants and make them more mobile. Because of their mobility, they could leak into the groundwater or accumulate in the food chain. It is still largely unknown whether plants take up nanoparticles via their roots or leaves and store them in their tissues[7]; this uncertainty applies all the more to any possible effects on plants.

Risks to living beings and human health: Research on the risks of the adverse effects of nanoparticles on health is also in its infancy. Research needs to distinguish between bound and free nanoparticles. It is clear that each product needs to be assessed individually. The following aspects are generally likely to generate adverse effects[2,5,6]:

- Nanoparticles are exogenous and largely insoluble in water.
- Some artificial nanoparticles are engineered so that they do not clump together. As a result they stay in the air longer, and the risk of their inhalation is higher.
- Due to their size, nanoparticles are also highly mobile. It is in principle possible to absorb nanoparticles from the air, water, food or through skin. They can get past the body's internal barriers and enter a wide range of tissue types. It has been established that nanoparticles get into the lungs, and from there go into the circulatory system and into various organs, including the brain. Nanoparticles can get into cells but they are not broken down and excreted by the mechanisms available in the body like other foreign substances.[5]

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[5] BAFU (2007) Synthetische Nanomaterialien. Risikobeurteilung und Risikomanagement. Grundlagenbericht zum Aktionsplan [Synthetic nanomaterials. Risk assessment and risk management. Basic report for the action plan].

[6] See 4; TA-Swiss, Ed. (2006). Nano! Nanu? Informationsbroschüre zum publifocus "Nanotechnologie und ihre Bedeutung für Gesundheit und Umwelt [Know Your Nano! Information brochure on the "Nanotechnology, Health and the Environment" *publifocus*]. Centre for Technology Assessment at the Swiss Science and Technology Council (TA-Swiss), Bern, Author: Herbert Cerutti.

[7] Nowack, B. und Bucheli, T. D. (2007). Occurrence, behaviour and effects of nanoparticles in the environment. Environmental Pollution 150: 5-22.

- It is still largely unknown whether and how nanoparticles can be excreted or broken down by the body or whether they accumulate there and which organs or cell organelles they could damage. Initial research shows that individual nanoparticles can have a toxic effect.[5,7]
- The effect on the quality of foods and animal feed is still entirely unknown.
- Nanoparticles may have a greater explosion risk or increased catalytic activity[5].

Sustainability and precautionary principle

As with every new technology, known and unknown opportunities and risks need to be weighed. Nanotechnology is notable in that it is an umbrella term for different applications, materials and fields of application which each can have very different effects on the environment and humans.[8] In keeping with the precautionary principle, risks need to be clarified before nanotechnologies are used.

How natural or artificial are nanoparticles?

Natural: nanoparticles present in nature: atoms, molecules, microfine dust from volcanic eruptions and combustion processes. nanostructures present in nature: in plants and on animals (e.g. gecko feet, lotus blossoms).

Nanoparticles can be produced from natural and nature-identical substances in various physical or chemical-synthetic processes. They may then have the same properties as the starting material or different ones. Table 2 shows a possible classification of nanoparticles, based on substance of origin, manufacturing process and properties. Unanswered question: Which nanoparticles could be defined as natural? Which variants might be allowed?

Table 2: Possible classification of nanoparticles, based on substance of origin, manufacturing process and properties.

Variants	Substance of origin	Manufacturing process	Property of nanoparticles
1	allowed in organic farming	physical	Same as larger particles
2	allowed in organic farming	physical	Very different chemical-physical properties, so acts differently on organisms
3	allowed in organic farming	chemical-synthetic	Same as larger particles
4	allowed in organic farming	chemical-synthetic	Very different chemical-physical properties
5	not allowed in organic farming*	- - -	- - -

* If the substance of origin is not allowed in organic farming, there is no need to discuss whether or not to allow nanoparticles.

[8] Von Gleich, A (2006): Chancen und Risiken einer mächtigen Technologie. Prospektive Technologiefolgenabschätzung [Opportunities and risks of a mighty technology. Prospective technology assessment]. http://www.cvl-a.tum.de/Download/WS_3_HtN_1.pdf

5 Assessment of nanotechnology by other organizations

Environmental, organic and consumer organizations tend to be critical of nanotechnology and they call for clear guidelines and risk studies. The Canadian ETC Group (Action Group on Erosion, Technology and Concentration) has been very critical[9] and calls for a moratorium until all the potential risks have been clarified[10]. They argue that nanotechnology changes both the animate and inanimate world in the most radical ways and that this is an extreme contrast to the holistic approach of organic agriculture. According to ETC Group, nanotechnology is worse than genetic engineering since it can be applied to and is effective in a wide range of sectors, cannot be monitored and has already been patented in many cases[11]. In a press release a broad coalition of consumer, environmental and organic associations called for strict oversight of nanotechnology (applying the precautionary principle, assessment of all risks from the outset, clear regulations).[12] The English organic agriculture organization Soil Association has published a “Draft Standard on Nanotechnology” in which they prohibit any use of products that have been produced using nanotechnology[13]. Coop Switzerland is holding back on nanotechnology[14].

6 FiBL’s preliminary assessment of nanotechnology

No specific products are pending for assessment, but this could change quickly. Due to the fact that there is no declaration requirement or regulation, it is also conceivable that nanoproducts are already being used in organic agriculture without our knowledge. Nanotechnology could be being used for food, packaging, machines and materials (surfaces), fertilizers, pesticides, drugs and auxiliary substances.

In the evaluation of nanotechnology, two principles have priority for FiBL:

1. **Organic food and animal feed should be natural.** Therefore we prohibit any use of nanoparticles that alters products (nanoparticles in food; any other change, e.g. caused by increased uptake of nutrients; nanoparticles as food/animal feed supplements).
2. **Organic production methods should be as close to nature as possible and not harm humans or the environment (i.e. be sustainable).** There needs to be an individual clarification of the origin, production, use and risks for each and every application of nanoparticles. The following list of criteria has worked well for this kind of clarification:

Evaluation based on criteria list:

- **Characterization:** Is it really a nanoparticle as defined? (Many “nano” products do not actually contain nanoparticles).
- **Necessity:** The product needs to provide a benefit in the context of the objectives of organic agriculture. The benefit depends on the specific product and its uses.
- **Environment:** The absence of adverse effects on the environment is for us a basic prerequisite for approval. Effects on the environment are currently still largely unknown. Special attention needs to be paid to the mobility of nanoparticles in the environment.
- **Human health:** For us, the absence of adverse effects on human health (particularly users and consumers) is a basic prerequisite for approval. These effects are currently still largely unknown. Special attention needs to be paid to the high mobility of nanoparticles in the human body.

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[9] ETC-group (2004). Down on the farm. The impact of nano-scale technologies on food and agriculture. Ottawa. http://www.etcgroup.org/upload/publication/80/01/etc_dotfarm2004.pdf.

[10] ETC-Group (2003). News Release: More Evidence for Moratorium on Synthetic Nanoparticles.

[11] Thomas, J. (2007). Nanotechnologie. Kleine Teilchen, die unsere Welt verändern [Nanotechnology. Tiny particles which change our world]. Ökologie und Landbau 143, 3, pp. 43-46

[12] ETC-Group (31.7.2007). Press Release: Broad International Coalition Issues Urgent Call for Strong Oversight of Nanotechnology. http://www.etcgroup.org/en/materials/publications.html?pub_id=651

[13] Soil Association (2005?). Proposed Ban on Nanotechnology. Information sheet. www.soilassociation.org.

[14] Hofer, B. (2006). Coop’s position on nanotechnologies. Adopted by Coop’s executive board. Basel.

- **Origin:** Of course existing standards relating to the natural or synthetic origin of materials for individual applications (packaging, auxiliary substances, food supplements etc.) need to be adhered to. There are different physical and chemical manufacturing processes for nanoparticles. It is an unanswered question how nanoparticles could be categorized and which could be authorized.
- **Public perception:** At present, nanotechnology barely registers on the public's radar, so it is difficult to estimate public perception. Consumers are particularly critical when technology leaves behind residues or affects the food's characteristics. If nanotechnology has positive effects on the environment or food quality (e.g. better packaging), though, acceptance seems probable.
- **Principles and traditions of organic farming:** Are there fundamental considerations regarding sustainability, the naturalness of organic products, food quality, ethics (manipulation of inanimate or animate matter) which result in nanotechnologies being rejected for organic agriculture (as with genetic engineering)? FiBL has no fundamental objections against nanotechnology, but calls for a rigorous evaluation case-by-case. There is no traditional use of nanotechnology in organic agriculture. That being said, nano-coatings have apparently been used for some time in packaging, but not referred to as such[15].

There is also the question of **controllability**: It only makes sense to prohibit something if that prohibition can be monitored. Controls are only possible if there is a recognized definition of nanotechnology. A declaration requirement would also greatly simplify the controls.

7 Conclusions and unanswered questions

Nanotechnology holds the promise of great potential, but it may also pose great risks. The longer we worked on this discussion paper, the more unanswered questions arose. This paper should therefore not be considered conclusive. We are still a long way off from conclusively assessing nanotechnologies or individual substances with nanoparticles, since we do not yet have the toxicological, ecotoxicological and ecological bases to do this. The serious lack of recognized definitions, statutory regulations and defined methods also hampers the assessment. The questions arises how we should deal with the wide gaps in knowledge.
FiBL is calling for a declaration requirement regarding the use of nanoproducts, as well as fundamental clarification of the risks to humans and the environment. Until the respective data are available, we advise caution. However, the non-existence of these data is not reason enough for us to reject this technology out of hand. Since benefits and risks can be different depending on the type of particle and the application, each situation needs to be reviewed separately. When doing so, the precautionary principle and viewing the entire life cycle in terms of sustainability are paramount for FiBL.

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[15] Wolfgang Lohwasser, Alcan Technology & Management AG Neuhausen: Nanobeschichtungen im Industriellen Massstab für Barrierematerialien in der Verpackung [Nano coatings on an industrial scale for barrier materials in packaging]. Lecture given in 2006