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Position paper on nanotechnologies

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ÖkoKauf Wien – The City of Vienna's green procurement programme
Working Group 23 – Nanotechnology

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Position paper on nanotechnology-based products – opportunities, risks, recommendations

(17 May 2011)

1. Background and motivation for preparing this position paper

More and more products made with the help of so-called nanotechnologies have entered the market in recent years. However, there is as yet no internationally accepted definition of nanomaterials, nor is there any requirement for mandatory labelling. It is therefore at present impossible to give a detailed overview of the nanotech products being marketed. Moreover, it is difficult to draw the line between "genuine" nanotech products and those merely labelled "nano" for marketing purposes.

Warnings against as yet unknown risks have been issued with respect to some nanotech products, while ecological benefits have been promised – and used in advertising to potential buyers – with respect to others. We at *ÖkoKauf Wien* have prepared this position paper as a broad guideline to assist in dealing responsibly with nanotechnology-based products.

2. What is nanotechnology?

The term "nano" derives from the Greek word *nanos,* meaning dwarf. One nanometre (nm) equals one billionth of a metre; relative to one metre, the size of a nanometre corresponds to that of a hazelnut relative to the earth. Nanotechnologies manipulate the structure of materials on the nano-scale, i.e. in a range from 1 – 100 nm. To do so, different processes from across the field of scientific disciplines (chemistry, physics, medicine, biology, etc.) are employed. The resulting nanotech applications are used for products in many different industries, such as cosmetics, building construction, domestic engineering, pharmaceuticals, textiles, lighting, surface-coating, food, optical products, electronics and garden/park management.

There is as yet no internationally accepted definition of nanotechnology. The most frequently used definition is that of the International Organization for Standardization (ISO), which defines nanotechnology as follows:

"Nanotechnology is the understanding and control of matter and processes at the nanoscale, typically, but not exclusively, below 100 nanometers in one or more dimensions where the onset of size-dependant phenomena usually enables novel applications."

The fact that the surface of a nanoparticle is very large in proportion to its weight results in new properties which the same substance or chemical compound does not have in its normal (i.e.

larger) particle size or dimension. Nanogold particles, for example, are red instead of yellow; also, they are highly reactive, whereas gold is normally a very inert material. Reactivity and colour are not the only properties that may be different in nano substances and compounds. Other properties that may change at the nano-scale are (water-)solubility, electrical conductivity, mechanical strength, toughness, magnetic behaviour, melting point and boiling point. Moreover, the nano particles of any given material may take not just one, but different shapes (spherical particles, fibres, tubes, platelets, etc.). Depending on particle shape and size (e.g., 10 or 100 nm), the nanomaterial may have different properties.

Nano products either contain nanomaterials, or their structure has been deliberately manipulated at the nano-scale, for example by making nano-sized pores in the material. Chemically produced coatings of nano-metre thickness are another nanotechnology application. Consumers can produce such coatings themselves by using store-bought nano sprays.

As nano-specific effects may also occur at larger particle sizes between 100 and 300 nm, the 100-nm limit defined in the above-quoted ISO standard is somewhat arbitrary. In assessing the benefits and risks of (nano-)materials, the specific properties of any given material are more important than the exact dimensions.

3. Benefits of nano products

Nanotechnology-based materials and products frequently have one or more of the following (beneficial) properties:

Antimicrobial effect: Nanosilver coatings on consumer goods such as textiles, washing machines, refrigerators, keyboards, food packaging, etc. continuously emit silver ions to reduce the reproduction of germs on or near the product surface.

Photocatalytic self-cleaning of surfaces: If **nano titanium dioxide** is added to paints and varnishes, or used in coatings on walls, roof tiles or glass panes, it breaks down organic dirt particles with the help of UV light. The dirt is washed away by the next rain shower, and the building requires less cleaning work.

UV protection: Nano titanium dioxide in sunscreen products provides highly effective protection against ultraviolet radiation and is already in widespread use.

Thermal insulation: Novel materials can achieve effective insulation even with low material thickness. These include evacuated **pyrogenic silica** in so-called vacuum insulation panels (VIPs), aerogels (nanofoam materials), either by themselves or in combination with mineral wool (Aerowool) and so-called phase change materials that can store heat without getting warm themselves. These products hold some promise for new, efficient thermal insulation systems for historical buildings, which may make a contribution to climate protection.

Weight reduction/light-weight engineering: With the addition of nanomaterials such as **carbon nanotubes** and **nano-scale silicon dioxide,** new materials that combine low weight and stability can be created. Applying these nanomaterials in the aerospace, automotive or building construction industries can help reduce resource inputs, especially fuel consumption.

The **lotus effect** is created by mimicking the nanostructure of the dirt-repellent and hydrophobic surface of the lotus leaf. Because of their lower mechanical stability, materials based on this effect are suitable for surfaces such as building facades that are not exposed to significant mechanical stress.

The **easy-to-clean effect** is generated by nm-thin, ultrasmooth surface coatings that repel dirt. Applications include bathroom tiles and shower booths. The coatings are permanently fixed onto the treated surfaces by what is called a sol-gel process that involves firing.

Anti-graffiti protection: Building exteriors are protected by "breathable" coatings based on **silanes** on which chewing gum and graffiti paint do not stick and can be removed more easily.

Scratch resistance: Nanoparticle coatings, for example **silicon dioxide,** are applied to optical lenses and in automotive engineering to create scratch-resistant surfaces.

Nanomembrane filter technology: Ceramic filters with nanopores help to clean wastewater and are already being used in some sewage treatment plants.

Flammability protection: Adding so-called **nanoclay** to plastics reduces their flammability; the material thus produced can be used for electrical wiring, among other things.

Fire protection: Nanoporous coats are used to make fire-resistant glass and similar products.

Water retention: A polymer of volcanic rock dust and colloidal (nanoparticle) silicate can hold up to thirty times its own weight in water. Added to soil, it helps reduce the need for irrigation, and is used, for example, in reforestation projects in arid regions.

Other nanotech coatings are used on materials for **improved wear and tear resistance, protection against corrosion** of metals, **anti-fingerprint, anti-condensation and anti-reflection effects,** e.g. on glasses.

4. Frequently used nanomaterials

The number of substances and compounds now available in the market in nano form, and the number of products in which they are used, has become too large to list them all in this paper. However, the following materials can be said to be used in significant amounts:

- Carbon: nanotubes, carbon black
- Metal oxides: SiO_2, TiO_2, aluminium oxide, iron oxide, zinc oxide
- Semiconductors: cadmium telluride, silicon, indium phosphide
- Metals: gold, silver, iron, cobalt

5. Legal situation

There is at present no specific legislative act that would regulate the registration, use, labelling and entry into the market of nanomaterials and nano products in the European Union. Although some relevant provisions can be found in various regulations, there is no legal obligation to register nanomaterials or nano products, and neither are there labelling requirements for products that contain nanomaterials. Limited labelling requirements will come into force in 2013 under the EU Cosmetics Regulation (Regulation (EC) No 1223/2009 on cosmetic products), but this will cover only certain nanomaterials used in cosmetic products. The legal position of the European Union so far has been that the REACH Regulation [1] sufficiently regulates the market entry and use of nanomaterials. As nanomaterials were not explicitly considered in the preparation of the REACH Regulation, however, a number of interpretative texts have since been issued by the EU Commission to inform those who produce nanomaterials and/or place them on the market about the specific actions they have to take under the REACH provisions.

Under the REACH Regulation, defined sets of data have to be submitted to the European Chemicals Agency (ECHA) concerning the potential hazards for human health and environmental safety of chemicals that are produced and/or placed on the market (beyond certain quantitative limits) in the EU. The Commission has now called for separate dossiers and safety data sheet information to be prepared for chemicals in nano form because they have different properties and may therefore also entail different hazards than the same substances in non-nano form. However, this will only be gradually implemented over the next few years. Many organisations have criticised this approach as inadequate, and some have called for a temporary ban on certain nano applications and products – especially those used on or close to the human body – until more data on potential hazards is available.

Among those that have made demands is the Wiener Umweltanwaltschaft (Vienna Ombuds Office for Environmental Protection), whose paper on nanotechnology is available (in German) at: http://wua-wien.at/home/umwelt-und-gesundheit/nanotechnologie

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[1] Regulation (EC) No 1907/2006 concerning the **R**egistration, **E**valuation, **A**uthorisation and Restriction of **Ch**emicals, which came into force in 2007.

6. Potential risks

It is not possible to make generalised statements about the risks inherent in nano products. Product-specific profiles have to be prepared on a case-by-case basis, taking into account the substance in question, its nano form and the application context, to arrive at preliminary conclusions concerning potential hazards. Importantly, methodologies to test nanomaterials for toxicity are still being developed, as existing standards do not appear adequate in every case.

In principle, however, the following can be statements can be made:

Nano particles are not a scientific invention. They are ubiquitous, and are generated in particular in natural and industrial combustion processes. The human body has therefore developed mechanisms to deal with nano-sized particles (nano-objects).

Nano-objects enter the human body most frequently via the respiratory organs, and some of them, especially fibre-shaped particles and certain metal oxides, can trigger inflammatory processes in the lungs (similar to asbestos). The skin and intestines are better barriers against nano particle invasion. There is as yet little knowledge about the effects of nano particles entering the human body. Such effects depend strongly on the entry path, the solubility and biodegradability of the particles, their propensity to quickly combine into larger units, whether and how they react with substances present in the body, and whether they are quickly excreted or tend to accumulate in certain organs. Airborne nano fibres that are not biodegradable should certainly be regarded as bearing greater risks than, for example, nano-scale fat droplets in food. Nano-objects that are firmly bound to a matrix in a product can be expected to be less of a hazard than nano-objects released into the atmosphere, such as nano cerium oxide, which is added to some fuels. Even less well-known than the health hazards are the environmental impacts of nanomaterials, for example, how the nano titanium dioxide in sun screen products affects lakes and other natural bodies of water used for bathing.

There is also still too little data on exposure, i.e. the amounts of nanomaterials people come into contact with, to provide a sufficient basis for comprehensive risk assessment. And very little research has so far been done on the risks involved in nanomaterials entering the waste stream or being recycled, e. g. in building materials.

Evidence of potential hazards has been found primarily with respect to carbon nanotubes (CNTs), nano titanium dioxide and nanosilver.

Certain **carbon nanotubes** resemble asbestos fibres. In animal experiments, CNTs have caused tissue changes that may be interpreted as an early stage of tumour formation. As carbon nanotubes are always firmly embedded in finished products, this evidence is relevant in particular with respect to adequate protection of workers' health.

Nano titanium dioxide has been shown to have a toxic effect on water organisms. As substantial amounts of this nanomaterial are being used as UV filter in sun screen products, it is also released into the environment, in particular into bathing waters. However, testing for its presence is methodologically difficult, which is why no impact analysis has been undertaken to date.

Nanosilver also poses an environmental hazard because silver ions have a strong toxic effect on microorganisms. Nanosilver coatings in dishwashers, washing machines and textiles may raise the amount of silver reaching the wastewater stream, adversely affecting the biological breakdown processes in wastewater treatment plants. Sewage sludge that contains (nano)silver may damage soil microorganisms if it is used to fertilise agricultural land. The silver content of sewage sludge in Vienna has already risen close to the maximum permissible level. (However, Vienna currently burns its sewage sludge.)

Nanosilver and silver in other forms are useful in medical applications because there are as yet hardly any silver-resistant germs. Widespread use of nanosilver in consumer products may however, while yielding only dubious benefits, result in germs becoming silver-resistant, so that silver would be lost for medical uses. Moreover, silver is a valuable raw material. Natural deposits are limited, and mining of primary silver cannot be significantly increased, so that silver recycling is bound to gain importance. But nanosilver in consumer products cannot be recycled at present; this application is therefore not sustainable.

7. Potential environmental benefits

A number of specific nanotech applications appear to hold some promise of potential environmental benefits. These include nano coatings that reduce the need for cleaning of large outdoor glass surfaces (see the paragraphs above on easy-to-clean, lotus and self-cleaning effects). Novel insulation materials that have to be applied in thin layers only or can be mixed into plasters, but still provide excellent thermal insulation, are another interesting option. LED illumination has already been introduced in the market.

Nanotech-based photovoltaic and solarthermal modules are currently being developed.

By reducing the weight of buildings and vehicles, designers and engineers hope to reduce resource needs and energy consumption. Note, however, that the production of some of the nanomaterials that are used to improve material strength requires enormous energy inputs; this is particularly true of carbon nanotubes.

No well-founded conclusion can be drawn concerning the ecological advantages of nanomaterials without comprehensive analyses which evaluate not only the performance (e.g. in terms of energy savings) of a given product during its useful life, but also take into account the energy inputs required in production, as well as environmentally sound disposal or recycling options after the end of the useful product life. Such comprehensive analyses, e.g. life-cycle assessment studies, are still largely missing today.

8. Nano products that are relevant in the City of Vienna's procurement processes

ÖkoKauf Wien has commissioned a research study (author: Sabine Greßler) that provides an overview of all those nano products available in the market today which may be relevant in the context of the City of Vienna's procurement processes. The study, which has been published on our website (www.oekokauf.wien.at), also lists potential ecological benefits and risks of these products. The results of this research will be integrated in the knowledge base of ÖkoKauf Wien.

Conclusions from the research study:

Given the high level of market penetration of nanotech processes and applications in the **IT sector**, the City of Vienna has become a regular buyer of products based on nanotechnological developments. On the one hand, it is near impossible to ask for non-nano products in the procurement process, on the other, it would make sense only in very few cases because these applications do not pose any identifiable risks. The only exception are **anti-microbial coatings** (e.g. on PC keyboards and mouse devices), which were judged to be unnecessary and should therefore be avoided.

With respect to **vehicles,** the situation resembles that in the IT field. Applications such as scratch-resistant paint, heat-reflecting and anti-reflection coatings of glass panes, which may help to extend the useful life and improve the operational safety of vehicles, have become increasingly widespread. **Nano cerium oxide** is added to diesel fuel to reduce fuel consumption and diesel soot emissions. However, the nano cerium oxide itself is released into the atmosphere, where it poses a potential health hazard when breathed in. As hardly any research has been done on this potential risk, the application is controversial. Moreover, no independent research has so far shown that adding nano cerium oxide to diesel does in fact result in substantially reduced fuel consumption. Its use can therefore not be recommended at present.

Because of its fear of suspicious consumers, the **food industry** is a sector where transparency is particularly low. At the same time, however, the industry is rather strictly regulated in Austria. Nanoparticle additives to be used in food products have to pass a special approval process even if the same substance in non-nano form has already been allowed on the market. Most experts believe that the addition of nano silicon dioxide (silica) flow agents to foods is harmless, as well as the production of stable emulsions from droplets in uniform nano size. Another application is the production of micelles which can be used to pack substances in aqueous solution which would otherwise be only fat-soluble.

Foods and juices can thus be reinforced with preservatives, antioxidants, vitamins or other essential nutrients that could previously not be integrated in these products. As a result we have to expect that nanotech processes will increasingly be used in so-called "functional food", i.e. products sold with a special health benefit claim (e.g. coenzyme Q10). Nanotech processes are also used to alter the properties of food packaging.

At ÖkoKauf Wien, the working group on foods took a critical view of applications that enhance the appeal and prolong the shelf-life of foods even as aging processes progress within the food. And if the trend continues to use provitamin A, which is only fat-soluble in its natural form, as a colorant in aqueous food products (such as juices), some consumers' vitamin A intake levels may rise to excessive and health-damaging levels. Various interior coatings for plastic bottles, as well as anti-microbial nanosilver coatings for packaging materials, were also seen critically, especially in view of the lack of research on the migration of these nanoparticles into foods and the potential long-term health effects this may have.

In the absence of specific nano labelling, direct control of the procurement process in this area is difficult. ÖkoKauf Wien has recommended, however, continuing current policies to favour tap water over bottled mineral water, focus on organically grown foods instead of "functional food" and make sure to avoid buying cutting boards or packaging materials with anti-microbial nanosilver coatings, should they be offered by suppliers.

A broad range of nanotech products have been developed in the **construction industry,** and some of these may offer relevant ecological benefits. At ÖkoKauf Wien, we see thermal insulation as a promising field. Nanotech materials could be useful for the retrofitting of historical buildings with thermal insulation in those cases where conventional insulation techniques cannot be used on facades of historic interest. Optimised solutions would have to combine **superior thermal insulation properties,** breathability, thin material layers and good workability of the material. Plasters with insulating properties (with added aerogel or nano paraffin balls) and novel materials such as aerowool (a combination of aerogel and mineral wool) may be able to meet these requirements if applied in combination, which would contribute significantly to climate protection. The City of Vienna will actively observe new developments in the market and may conduct pilot projects to accelerate the market introduction of good low-risk solutions.

Other new developments include (nano-thin) protective coatings for buildings. Applied to the building exterior, these coatings repel dirt and water. There are different products in this field in terms of production process and effect: self-cleaning photocatalytic coatings (with nano titanium dioxide), breathable anti-graffiti coatings, easy-to-clean coatings with ultra-smooth surfaces and lotus-effect products whose structure mimics that of a lotus leaf (see also point 3 above).

These coatings are available for facades, glazing, roof tiles, etc. The may yield environmental benefits if the surfaces thus treated do in fact need less frequent cleaning, reducing the amount of cleaning agents required, or if the coating helps prolong the life of the building. However, there is no substantial independent research on these effects as yet, and any environmental benefits found would also have to be seen in comparison to the resource needs of the nanomaterial production process and the ecological burden caused by the release of hazardous substances (such as nano titanium dioxide) into the environment. Comprehensive assessments of all these factors are not available at present.

Products are already in the market in which nano coatings are added by firing as an integral step in the production process. This is certainly a better option than adding coatings at a later point, because the fired coatings have higher durability and a lower risk of hazardous substances migrating into the surrounding medium. At ÖkoKauf Wien, we are researching what the experience has been with applications that are already being used, for example by the Austrian Federal Rail (ÖBB).

Easy-to-clean and anti-microbial coatings for indoor application, e.g. in sanitary facilities, will deliver benefits only if cleaning schedules and hygiene instructions are adjusted to their use. With respect to **paint for indoor use,** the effect is bound to be smaller as there is hardly any UV radiation indoors. At the same time, interim products from the degradation of harmful substances may accumulate in the air. It is therefore a long-standing policy of ÖkoKauf Wien not to allow anti-microbial paint additives (e.g., nanosilver) for routine applications. We do not see any promising applications at present.

New plastics with nanoclay additives may be an interesting application. Given their **low flammability,** these materials are potential substitutes for conventional anti-inflammatory agents (which often contain bromine). They are used, among other things, in cable sheathing, power connectors and electrical devices.

Air-conditioning and ventilation systems with germ- and pollutant-repellent nanosilver or nano titanium dioxide coatings may be interesting applications if testing based on international standard methods shows sufficient effectiveness, in which case these nanomaterials could substitute the continuous use of disinfectants.

Nano coatings can also be applied to **textiles.** Research has shown that the lifespans of anti-microbial (nano)silver coatings vary considerably, and that **nanosilver** is released through abrasion and washing. Apart from very specialised applications (e. g. in hospitals' operating rooms), there is no reason to use nanosilver coatings in textiles or other products that are close to the human body.

Various coatings are found in **household appliances.** Anti-microbial nanosilver coatings, for example in dishwashers or washing machines, while not providing any relevant benefits, cause additional silver to be released into the environment. On the other hand, nano-ceramic anti-corrosion coatings may be useful substitutes for the ecologically harmful iron phosphating process.

A new product has been developed in Germany for **park and garden management**. Called Geohumus, it is a polymer of volcanic rock dust and pyrogenic silica which can retain thirty times its own weight in water in a way that keeps the water available for plants. Its use helps to reduce the need for irrigation, and the new product holds promise for very arid regions of the world. It has already won several environmental awards and could also be added to soil for trees in dry urban environments.

For more application examples, see the above-mentioned report at www.oekokauf.wien.at.

9. Conclusion

Nanotechnology is a cross-disciplinary field whose opportunities and risks have to be gauged through a highly differentiated approach. Generally, it can be said that nanotechnological innovations often aim at the development of new product properties that will increase customer convenience, whereas environmental soundness is not a focus of nanotechnological development. Even so, some applications do hold ecological promise. It must be noted, however, that comprehensive (life-cycle) studies have shown an overall environmental benefit only for a few individual applications until now.

With respect to unknown risks, some experts, for example at the Institut für Risikobewertung (Federal Risk Assessment Institute) in Berlin, Germany, have **warned against** broad use of **nanosilver,** especially in products used on or close to the human body, as long as data is still scarce concerning potential negative effects on human health and the environment. Some research studies are also critical of products that release **nano titanium dioxide** into the environment, a product group that has already found widespread use as UV filtering agent in sun screen lotions. The production of **carbon nanotubes** requires extremely high amounts of energy. This material should meet the highest standards, not only in terms of worker health and safety, but also in terms of energy savings during the useful life of the products in which it is used.

With respect to applications that promise ecological benefits, in particular in the area of building construction, we have concluded that active market observation and possibly also pilot projects are advisable.

10. Other recommendations

ÖkoKauf Wien generally recommends that suppliers who claim specific nanotech properties for their products be asked to provide the following:

1. evidence that the product is fit for use as claimed;
2. independent research studies that substantiate any claims of ecological benefits;
3. the results of an independent risk assessment study concerning any hazards to human health and/or the environment, especially if the product in question may release nanomaterial(s), or if its use entails human and/or environmental exposure to the product.

11. Links to other relevant publications

ÖkoKauf Wien, preliminary assessment of risks and opportunities of nanotechnologies in the context of the City of Vienna's procurement processes, research study by Sabine Greßler: www.oekokauf.wien.at

Institut für Technikfolgen-Abschätzung (Institute of Technology Assessment), Vienna, project "NanoTrust": http://nanotrust.ac.at/

Umweltbundesamt (Environment Agency Austria), Vienna: http://www.umweltbundesamt.at/umweltschutz/chemikalien/nanotechnologie/

AGES, Vienna: http://www.ages.at/ages/ernaehrungssicherheit/nanotechnologie/

Friends of the Earth, nanotechnology and food: http://www.foeeurope.org/activities/nanotechnology/index.htm

Data base on nano products in Europe: http://www.nanoproducts.de/

Data base on nano products in Germany: http://www. bund. net/nc/bundnet/themen und projekte/nanotechnologie/nanoproduktdatenbank/pr odu ktsuche/

BUND (Friends of the Earth Germany): http://www. bund. net/bundnet/themen und projekte/nanotechnologie/

EMPA, Switzerland; Wie metallhaltige Nanopartikel Zellen stressen können (How metal-containing nano particles may stress cells); http://www.empa.ch/plugin/template/empa/*/70135/---/l=1

Nanotruck, Germany, information on nanotechnology: http://www.nanoTruck.de

Bundesinstitut für Risikobewertung (Federal Risk Assessment Institute), Germany, on nanosilver: http://www.bfr.bund.de/cd/50963

Bundesministerium für Gesundheit (Austrian Ministry of Health), study on nanosilver in cosmetics, sanitary products and food contact materials: http://www.bmg.gv.at/cms/site/standard.html?channel=CH0983&doc=CMS1266311358101

Aktionslinie Hessen-Nanotech (regional government of the state of Hesse, Germany); information and publications about applications: http://www.hessen-nanotech.de/

BUND (Friends of the Earth Germany) on nanosilver: http://www.bund.net/index. php?id=4433

Friends of the Earth on cosmetics:
http://www.foeeurope.org/activities/nanotechnology/nanocosmetics.pdf

BUND (Friends of the Earth Germany) on food:
http://www. bund. net/filead min/bund net/publikationen/nanotech nolog ie/200803 11 nanotechnolog ie lebensmittel studie.pdf