GOOD USES OF NANOMATERIALS IN THE NETHERLANDS.

Results of a survey by Hogeschool Zuyd, Centre of Expertise in Life Sciences , Arbo Unie, Expertise Centrum Toxische Stoffen (ECTS), and ARBOdienst DSM, Geleen

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Introduction

Applications of nanomaterials and more specifically, engineered nanoparticles are expected to enable huge economic and technological possibilities. Nanotechnologies are being increasingly used in science and industrial development in widely different applications (Royal Society, 2004). The definition of engineered nanoparticles, i.e. poorly biodegradable particles having a diameter between 1 and 100 nm and intentionally engineered, produced or applied because of specific properties, which may be based on shape, size, surface properties, or chemistry. Some of these special properties of engineered nanoparticles, in particular their reactivity, have raised concerns regarding human health (Maynard et al, 2007). Due to these concerns scientists, regulators, and industry have initiated efforts to gain knowledge about worker exposure and to define safe uses of the different engineered nanoparticles (SCENIHR, 2007; Nanosafe, 2008). In 2007-2008 we have made an inventory of the use of synthetic nanomaterials in the Netherlands. The main objective of this investigation was to obtain an overview of the current good practices using engineered nanoparticles, and the associated occupational hygiene measures, instructions, communication in the economic chain and the disposal of nanoparticle-containing waste. For the purpose of our investigations nanoparticles may be encapsulated in a matrix. The study was initiated and funded by the Ministry of Social Affairs and Employment and the Ministry of Housing and Spatial Planning and Environment.

Brief outcomes of the survey

Similar to other countries, it appeared very difficult to map institutions and companies that are active in Nanotechnologies. In this survey we approached 122 potential candidates (see figure 1), of which 62 were found to be not relevant to our studies since either they did not use engineered nanoparticles (n=42), or since they were not using these materials in a Dutch subsidiary (n= 8). Sixty candidates did meet the inclusion criteria, and 37 of that population participated in our interview based survey. Among these there were 26 private companies and 11 academic or research organizations (see figure 2). The number of SME's was 11 out of 26 (42 %), containing both producers (n=5) and users (n=6)..

In summary, 37 companies and research institutions have actively participated in the survey. All companies were visited by the researchers, at which occasion an interview was completed and the facilities were visually inspected. This led to the following aggregated set of data on conclusions, ranked by original research questions.

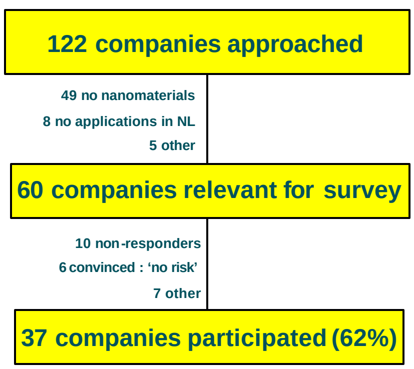

Figure 1 Use of nanomaterials and potentially exposed population

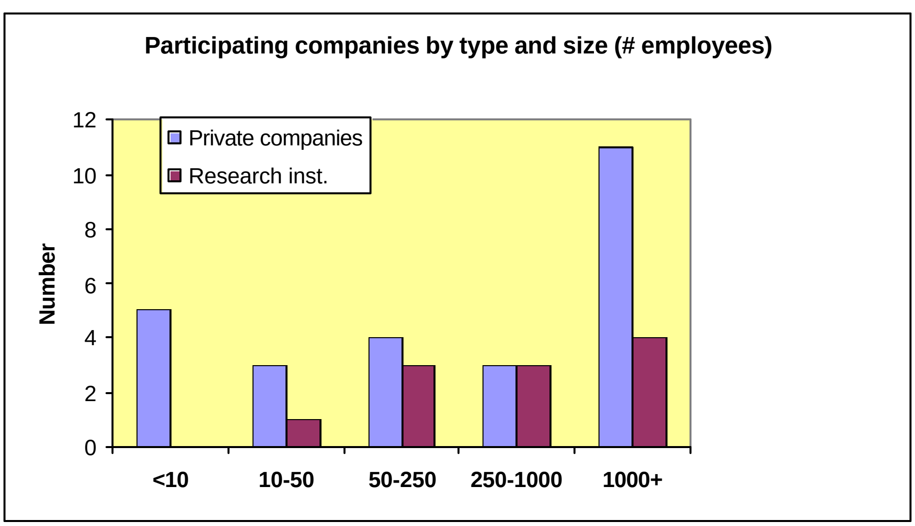

Figure 2. Participating companies by type and size

Compared to other surveys the response is high when denominated to the relevant companies (n= 62 %, n=60) or to the total number of companies approached (n=122, 30 %). The response rate in other international studies varied between 7 and 21 %. Independent checkpoints such as patent analysis, tax details from stimulated technology areas show that a number of larger players in the Netherlands (Philips, ASML) did not participate. It is impossible to predict how this has affected the qualitative and quantitative outcomes of this study, but our data are similar to recent international studies (Gerritzen et al, 2006; Tonning & Poulsen, 2007; Schmid & Riediker, 2008). In particular the nature of mostly used nanoparticles shows that currently used nanomaterials are still of the first generation, including carbon black, metal oxides and amorphous silica. Many other materials are being developed or being explored for application. The expected applications and production will start after the R & D phase is closed and lead to a significant increase in use of newer nanomaterials within the next 3-5 years. These concern new textiles, the automotive sector, ceramics and nanocomposites. Three companies indicated that production will soon follow after successful closure of the R & D phase.

The most frequent uses of engineered nanoparticles were found in surface and coating technology, and research applications are a good runner-up. By far the most important applications are in materials and material development (15/37). The nanoparticles that are used in the largest quantities in the Netherlands (more then 10 tons/year) are carbon black, amorphous silica and alumina oxides.

Table 1. Overview of the most important application areas, identity and amounts of nanomaterials used in the Netherlands. Survey based outcomes.

Application area (number respondents)	**Nanoparticle**	**Use / production (kg / yr)**
Assembly/recycling (2)	Carbon black Carbon nanotubes	2000 0.1- 1.0
Electronics (3)	SiO_2, amorphous	100 - 1000
Research (6)	Metals (Au, Ag, Pd) Clays Carbon nanotuves, C60	0.1 – 1.0 1 0.1 - 10
Health & Food (4)	FeO, SiO_2-amorphous Fullerenes (C60)	10 -100 10 - 100
Surfaces & Coatings (12)	TiO_2 SiO_2, amorphous Carbon black SnO_2 Alumina oxides	100 – 1000 10,000 100,000 2,000 100 - 200
Separation (1)	Carbon black	Same as in assembly

The use of other engineered nanoparticles (carbon nanotubes, nanosilver, iron oxides) was only in small quantities. Within the total worker population that is employed by all participants (n= 41.000), only 400 workers have a regular contact with nanoparticles. About half of these workers handle carbon black, amorphous silica and metal oxides or combinations thereof. In the academic and research sector a total of 137 was observed to handle many different nanoparticles in experimental stages. The amounts of these latter classes of nanoparticles do not exceed 1-100 grams/year.

Occupational hygiene measures to control exposure to nanoparticles

There is a clear awareness of the potential risks of nanomaterials among the participants in this survey. Almost all (92 %) of participants performed or are in the process of performing a hazard and risk assessment analysis specific for nanoparticles. However, in most cases this assessment is not included in the formal process to comply with Dutch law. Most companies and institutions (n=25, 68 %) have done this assessment on application level or responsible company unit. Five of these (25 %) indicate that they have not yet completed their judgment and the rest (75 %) has come to the conclusion that this procedure and measures fully covers the potential risks of exposure. Only 6 companies have done additional (for nanoparticles relevant) exposure measurements. Almost 25 % of all participants indicate to have a company policy to deal with potential exposure to nanoparticles. However, the content and background of the chosen policies differ widely, and seem to be based on 1) pre-emptive choice on specific nanoparticles, 2) the general exclusion or handling of nanomaterials as a toxic substance, 3) choices on the physical form of the nanoparticles. The decision not to use nanoparticles as powders, but only in a matrix, or the approach to bring nanopowders as quickly as possible in dispersion appear to be most dominant good practice in general occupational hygiene policies.

Good use and good practices

The control measures currently taken by companies are presented in figure 3. Briefly:

- The type of occupational hygiene measures is related to the extent of use and the physical form (nanopowders, embedded in matrix, dispersion). Of the participants that were using nanopowders 50% worked in a closed system. Apart from that local ventilation was the type of measure encountered most frequently in companies using nanopowders.

- As a general principle, ventilation seems to be the most frequently applied measure, using fume hoods (n=19) and other forms of local ventilation (n=9), sometimes with HEPA filters as a backup. Recent studies have shown that these filters are very efficient to remove nanoparticles from the air.

- Logistic measures within the organization, such as reduction of exposure duration or limiting the number of employees that can have contact with engineered nanoparticles is used in 5 companies as a control measure.

- Participants that use nanoparticles in a matrix apply less control measures than those working with nanopowders. Those participants using nanoparticles in a matrix do this in a closed system in 25 % of cases, and again ventilation was the most common (56 %) practice.

- No differences were observed in control measures between academia and research and private companies. Academia is a bit more active in training and education, but the line of measures is qualitatively similar.

Only 3 companies indicated that they are not currently taking measures to control exposure. Two of these had no production or use yet, and the other company was not sure whether nanoparticles where present in the intermediate product. Other participants indicated that current practices were sufficient and effective, although one had little to no data to validate this.

The effect of current good practices?

- Very little is known about the effect of control measures, since no systematic exposure monitoring is done. In only 22 % (N=8) of cases some kind of exposure monitoring has been performed, and this is usually a single time measurement and now always the relevant exposure entity (in some cases only gravimetric sampling was performed).
- There is a clear need for more information and guidelines on good practices in handling nanomaterials and nanoparticles. This need relates more specifically to the effectiveness of filters, gloves, and ventilation and inhalation protection.

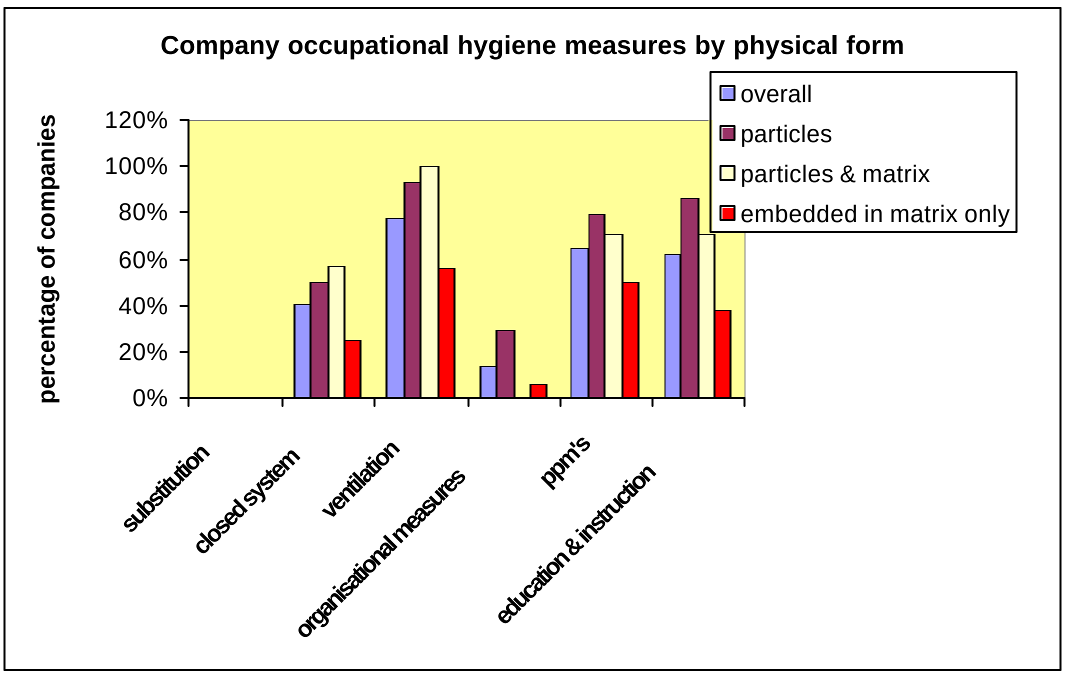

Figure 3 Overview of control measures and good practices currently implemented by companies, by physical form of the nanoparticles

Dissemination of current know-how on best-practices

- Recently a number of documents and guidelines have been published relating safe handling of nanoparticles at the workplace (NIOSH, 2006; Aitken et al, 2004; BSI, 2007; BaUa & VCI, 2007, Nanosafe, 2008 & Schulte et al, 2008). The various documents differ in extent of detail, and have been reviewed briefly in this study. The participants in this survey use a number of the guidelines mentioned in these documents. Based on the observed good use and handling and the international guidelines, we have constructed a decision tree that can be used for reflection on current work practices as well as to improve current occupational hygiene measures.

- Most users of nanomaterials indicate that they would benefit from independent support on the use of occupational hygiene practices and environmental monitoring of nanoparticle exposure. A virtual centre of expertise could be an approach to merge the competence and power of available institutions. Such a centre could also disseminate most recent know-how on best-practices.
- Dissemination needs a target, and therefore a database needs to be generated of companies and institutions that work with nanoparticles or make products that may release nanoparticles during their lifecycle. Such an initial database can be created from the database generated during this survey, and data from research programs and industrial branches.
- Communication of best-practices guideline is an absolute prerequisite visualizing and improving current good practices to handle nanoparticles, and allow intervention by companies and professional services. The proposed guideline in this study (Borm et al, 2008) can be used as a first version.

Communication of health- and safety information between producers and users

- The exchange of information in the chain is poor. Almost 50 % of the participants spend no effort at all in information on presence and/or hazards of engineered nanoparticles. This is true in both directions, i.e. between suppliers and users, and with users downstream.
- The safety-information sheets (MSDS) usually do not give information on the presence of nanoparticles and the potential hazards of nanoparticles in their product. Therefore potential risks are very hard to recognize for downstream users of products.

Common practices regarding the disposal of engineered nanoparticles containing waste

- Almost all participants (92 %) use regular waste-disposal systems to deliver nanoparticles. Although in single cases nanomaterials are kept separate from other materials, the eventual way of collection and fate are the same as for other waste products.
- The chemical nature of the nanoparticle or the matrix in which it is contained are the major determinants for the waste container that is used.

Conclusions

The discussions and media-attention on hazards of nanotechnologies have not been unnoticed in academia and private sector. Most of the participants and also those not-participating are aware of ongoing discussions and needs for further research and regulation. Regarding good and best-practices in handling nanoparticles, there seems to be a general principle to use nanoparticles in a matrix or dispersion. The occupational hygiene measures taken to control exposure are largely similar to those observed in other countries (Gerritzen et al, 2006; Tonning & Poulsen, 2007; Schmid & Riediker, 2008), and do not differ between companies and academia. Little data is available on the effectiveness of these occupational measures, since only incidental measurements have been performed. Existing measures and guidelines are not always adequately followed, which is best illustrated by the poor communication between producers and users in the value chain and the lack of information in safety-data sheets.

This survey has exposed a number of issues that deserve attention in future work. First, its is very hard to identify the target group due to the enabling character of nanotechnologies, and for future actions towards this group (dissemination, education, regulation) a better understanding of this dynamic community is needed. Secondly, current applications of nanomaterials are mainly in surfaces and coatings and use mostly first generation nanoparticles such as amorphous silica, metal oxides and carbon black. As opposed to the newer materials that are being developed, these first-generation nanoparticles are well characterized from a toxicological point of view and treated as substances. Current developments indicate that in the near future many different nanoparticles will be used, without the toxicological database available for the first generation products. Thirdly, most users and producers have little know-how on the methods that can be used to detect presence of nanoparticles in products or workplace environment.

It is recommended to repeat a survey like this at least twice in the next 10 years to keep up with the rapid developments and implementation of engineered nanoparticles in new processes and products.

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