NANO IN FURNITURE

Within the European Social Dialogue, the EFBWW (European Federation of Building and Wood Workers), EFIC (European Furniture Industries Confederation) and UEA (European Furniture Manufacturers Federation) have taken the initiative to commission IVAM UvA BV to investigate the current awareness amongst stakeholders and to make an overview of actual nano-products at the European furniture market.

This executive summary summarizes the results described in detail in the report "Nano in Furniture, state of the art 2012". Central questions addressed are:
What types of nanomaterials are being used in manufacturing of furniture products?
What are near future perspectives for using nanomaterials in furniture manufacturing?
What health and safety issues may play a role for workers at the workplace?
What would a precautionary safe workplace look like?

In depth study of the European furniture industry and interviews with furniture companies and material suppliers shows that the market for nanomaterial use in furniture products in 2012 is still in an early phase of development. Nanotechnology may have huge implications for the future of furniture manufacturing; on furniture quality and functionalities but also on environmental, occupational and public health performances related to the manufacturing and end-products.

IVAM UvA BV

NANO
IN FURNITURE

State of the art 2012, Executive Summary

Fleur van Broekhuizen
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AUTHORS
F. A. van Broekhuizen (IVAM UvA BV, NL)

STEERING GROUP
R. Gehring (EFBWW), C. Ravazzolo (EFIC), M. Eirup (EFIC), B. de Turck (UEA), R. Rodriguez (UEA),
U. Spannow (BAT, DK), J. Waage (FNV Bouw, NL) and J. Moratalla (AIDIMA, ES)

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MORE INFORMATION about the report can be obtained from:

IVAM UvA BV
Amsterdam-NL
Tel: +31 20 525 5080
www.ivam.uva.nl
Email: office@ivam.uva.nl

Cover and interior design: Beryl Natalie Janssen/Cologne

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INTRODUCTION

WITHIN THE EUROPEAN SOCIAL DIALOGUE, the EFBWW (European Federation of Building and Wood Workers), EFIC (European Furniture Industries Confederation) and UEA (European Furniture Manufacturers Federation) have taken the initiative to commission IVAM UvA BV to investigate the current awareness amongst stakeholders and to make an overview of actual nano-products at the European furniture market. This executive summary summarizes the results described in detail in the report "Nano in Furniture, state of the art 2012". Central questions addressed are:

- What types of nanomaterials are being used in manufacturing of furniture products?
- What are near future perspectives for using nanomaterials in furniture manufacturing?
- What health and safety issues may play a role for workers at the workplace?
- What would a precautionary safe workplace look like?

"Nano" specifies an order of magnitude. Nanotechnology simply means the ability to observe, monitor and influence materials (and their behaviour) down to the nanometer (nm) detail (e.g. a size range about 10,000x smaller than the thickness of a human hair). This involves advanced imaging techniques to study and improve material behaviour, but also the design and production of very fine powders, liquids or solids containing particles of a size between 1 and 100nm, so called nanoparticles. A nanomaterial (MNM) is a material that consists at least for 50% of nanoparticles[1]. Companies make use of nanomaterials to give their products new or improved properties (nanoproducts). The furniture industry isn't a large user of raw nanomaterials, but does use nanoproducts. Examples of these are high scratch resistant lacquers, antibacterial, self-cleaning or easy-to-clean coatings and ultra-strong concrete material for kitchen and street furniture applications.

At the same time, there is serious concern about possible health and safety aspects of MNMs. MNMs may behave more hazardous to humans than their traditional micro scale equivalents because MNMs:

- are so small that they may penetrate the human body more easily (i.e. via the nasal nerve system, lungs or skin);
- are so small that their powders may behave like gasses;
- may induce specific toxicity responses due to their shape and large specific surface area;
- may show different chemical and physical properties i.e. electrical conductivity.

The toxicity mechanisms of MNMs are just beginning to be understood. At the same time, the exact mechanisms at play may vary per individual MNM and many unknowns remain to date. However, one can expect that the toxicity profile is at least partly related to the unique behaviour that makes them interesting for product innovation in the first place. Typical adverse effects observed range from inflammation, cardiovascular diseases, cell death, scar-tissue forming (for example in the lungs) and malfunctions in embryos to the development of cancer cells in affected tissue. Adverse effects observed for MNMs though, depend strongly on the dose and duration of exposure. Adverse effects also depend on the form of the MNM exposure. Preliminary findings for example, do hint that MNMs may be highly toxic in pure form but do not necessarily show this toxicity when exposure occurs, when the MNM is embedded in a matrix.

This executive summary summarizes the state of use of nanomaterials in furniture in 2012, near future potentials, health and safety issues and good practices for organising a safe workplace in the European furniture industry.

[1] A definition was adopted by the European Commission on the 18th of October 2011. For more details: http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/11/704&format=HTML&aged=0&language=EN&guiLanguage=en

MARKET AND PERSPECTIVES

NANOTECHNOLOGY may have huge implications for the future of furniture and the variety of its applications; on quality and functionalities but also on environmental, occupational and public health performance. However, looking at the market of 2012, the use of nanomaterials (MNMs) in furniture manufacturing and products is still in an early stage of development. First field experience does suggest main application areas in the field of coatings, nanocoatings, with a market size that is probably less than 1% of all other "non-nano" coatings applied. The MNM-market in furniture is coloured by a lack of traceability, ignorance on availability or use, secrecy surrounding R&D activities and a reluctance of furniture manufacturers to expose themselves as MNM-users as a consequence of the world wide social debate on health and safety issues and related uncertainties.

MARKET POTENTIALS

In the early days of the millennium, MNMs were advocated as the most important innovation that would colour the future of furniture R&D. High expectations were launched, but to date only little R&D has resulted in successful market products. As a consequence of the world-wide economic crisis, over the last years investments in R&D ceased and further developments slowed down.

One area where the use of MNM in products gains successes is in quality improvement of furniture to reduce service and maintenance needs. Hospitals and (residential) offices are examples of places where these products can be of high added value. Nano-SiO_2, liquid glass, is one of the MNMs most mentioned in this context. Liquid glass is used in easy-to-clean, water-repellent, oil-repellent and anti-graffiti coatings. Liquid glass is also applied in high scratch resistant lacquers or in coatings to protect metal, wood or stone against erosion and wear processes. It may protect wood against algae growth and attack by other organisms like woodworm or termites. Furthermore, nano-SiO_2 is used to achieve an ultra high strength and high density concrete that is excellent for use in kitchen and street furniture. Direct contact with furniture manufacturers and their suppliers suggests that the market for these applications is gradually increasing.

Another area of MNM-success is that of bactericidal or self-cleaning coatings. Nano-silver and nano-TiO_2 are two MNMs most observed for this function. Both MNMs are relatively expensive and find their application in surface treatment of furniture in medical centres and other locations where infection is to be prevented, i.e. the food sector, pools or saunas or even public transportation.

A last area where MNMs are introduced is in the prevention of decolourisation and UV degradation of materials. Nano-clays are MNMs that are used to stabilise pigments. Nano-TiO_2, nano-ZnO and nano-CeO_2 are MNMs that are used as UV-blocking agents, for example in wood protecting coatings.

Still, many more material applications have been described in literature, or are available at the market, i.e. smart glass, nano-cellulose textile and adhesives. See also the full report "Nano in Furniture, state of the art 2012" for a detailed outline of different nanomaterials available for the furniture industry. In 2012, these applications seem more or less unexploited. In the near future, MNMs may play a role in the further development of furniture performance and the design of a more sustainable furniture industry. MNMs might facilitate:

- the production of more light, strong and durable materials;
- the introduction of new material functionalities;
- the substitution of hazardous flame retardants for novel MNM-based systems;
- the use of novel gluing techniques and the formulation of MNM-based adhesives;
- the design of smart furniture, like kitchen cabinets that sense you run out of pasta or a chair that changes colour upon the daily desire of the customer.

An overview of different product groups available and used in furniture products is given in the table below.

Nylon fabric treated with a water repellant, easy-to-clean coating based on liquid glass.

TABLE 1 Overview of nanomaterial functionalized product groups available for use in furniture in 2012

PRODUCT GROUP	DESCRIPTION	RELATIVE USE IN FURNITURE[2]
Glass	Over the last years, nanotechnology has been applied to develop and produce different types of glass, i.e. non-reflective glass, privacy-glass, thermal insulation glass (based on InfraRed light reflection or absorption) and biocidal glass. Many applications could make use of these. Think about e.g. glass-cabinets, in museum applications, lamps, tables, office furniture or medical furniture. However, according to large market players, their market penetration into furniture is low.	Low – not detectable
Composite material	At the level of R&D, there is a lot of activity in the field of nanocomposites. Both for plastic composites and for wood composites. For wood composites, potential applications have been described that make use of nano wood fibre to optimize the strength and performance of composite materials. First contacts with the composite industry however, do suggest that this application has not reached the market yet. Some examples are: • novel flame retardant systems • nano-cellulose as reinforcement fibre • nano-silica for strength enhancement	Low – not detectable
Wood	In forestry (the production phase of wood), nanotechnology is used to optimize biocide systems for wood-preservation and a more sustainable wood production. Before the wood is used in a product, nanotechnology can be used to study wood performance in more detail and hence make better use of the wood potentials. In the use phase of the wood, novel techniques are in development for wood surface modification to improve the durability of the wood in its function and UV-resistance.	Low – not detectable
Metal	Metal improvements using nanotechnology take place at the level of metal-structure modification or at the level of surface modification. Electroplating is one example of a technique making use of nanomaterials. Hardening of steel is another example.	Low – not detectable
Textile	Many different potential applications of nanomaterials for textiles are described and found in various products. However, in the furniture sector, only stain repellent, easy-to-clean and antibacterial textile are found to be used. High absorbing textiles made of nano-cellulose are a fourth application that is gaining market.	Small but increasing
Concrete	Concrete is used primarily in outdoor public spaces. Silica fume (nano-silica), used in the production of Ultra High Performance Concrete (UHPC), and nano-TiO_2, used to provide the concrete with a "self-cleaning" surface are two possible applications of nanomaterials that may be of additional value in this sector. Prima-Marina, by Escofet® is one example of a product line of outdoor benches and tables that make use of UHPC, also known as liquid stone. Carbon nanotubes are MNMs that are currently explored for their function to improve the strength of concrete composites and may be near application.	Medium and more and more used
Adhesive	Nanomaterial adhesives that are described for furniture are based on silica or silane compounds that act as cross-linking agents within the adhesive polymer structure or as a stabiliser of water based adhesives to fine tune the viscosity of the product. The additive dispersion Dermocoll®S by Bayer, is an example of the latter and consists of a silica-polyurethane dispersion. Another type of developments act at the level of surface-roughening. The nano-roughened surface enhances the adhesive strength and lowers the amount of adhesives needed.	Low – not detectable
Coating; water or oil repellent	Water or oil repellence can be achieved using different nanotechniques. It can be used on textiles, wood or metals to reduce erosion and wear and protect against stains, fingerprinting etc. However, it can also be used on wood composites to prevent swelling through water absorption. The liquid glass technology for example applies a porous water repellent coating that still allows the underlying material to breathe.	Relatively high and increasing
Coating; scratch resistance	An upcoming market of nanoproducts is high scratch resistant paints or lacquers. This can be for wooden systems like tables, chairs, doors or floors, but may also be used on any other "soft" material in furniture that is used intensively like plastics or laminated boards. Different types of coating systems are found with this typical character that can be either aqueous or non-aqueous based.	Relatively high and increasing

[2] Because of the pioneering character and limited market penetration of MNMs used in furniture, it was not possible to quantitatively determine the use of MNMs in different product groups. The occurrence and market perspectives of MNMs in products for furniture are therefore indicated relatively. "High" should be interpreted as *relatively high with respect to all MNM enhanced product groups observed available on the market.* "Low" should be interpreted as *not detectable* even though it is imaginable that it is used without communicating the use as nano. "Small" means *small but observed.*

Coating; anti-graffiti	Anti-graffiti coatings are described for their outdoor applications like street furniture. However, they may also be used on furniture for children or in kitchens to serve the multipurpose of furniture and white-board.	Medium and increasing
Coating; easy-to-clean	Dirt repellence is one of the applications described in which nanomaterials are used to improve material surfaces for furniture. This technique is often based on the "lotus leaf" principle. The lotus leaf consists of tiny hairs that reduce the surface tension and prevent oil and water to adsorb. As a consequence "dirt" pearls off easily. When this principle is applied to furniture material, this material surface becomes "easy-to-clean". This implies for example that fewer detergents are needed for cleaning activities, also when this involves textiles.	Relatively high and increasing
Coating; UV protection	Furniture used outside is constantly being exposed to all sorts of weather conditions including UV radiation. UV radiation enhances the deterioration of materials and coatings and one way of delaying this process is by the addition of UV absorbing agents. Especially for wooden surfaces the benefits of nano-additives to facilitate this absorption have been described. UV absorbing additives are also used to enhance the lifetime and colour-fastness of paints or coatings that deteriorate as a consequence of UV exposure.	Small but increasing
Coating; self-cleaning	Self-cleaning coatings actively break down organic material (pollutants and organisms). These may be interesting to explore for kitchen furniture where one finds a daily deposit of very thin layers of baking oils and other food related contaminants (proteins, carbohydrates). Also in areas like hospitals, saunas, swimming pools etc., these might be interesting, even though it is no alternative for normal cleaning operations.	Low, increasing in specific areas
Coating; bactericidal	Bactericidal coatings kill bacteria and other micro-organisms such as algae or fungi that try to survive on that coated surface. This can be an important functionality for furniture in large public spaces like the metro system, trains, offices, day-care, hospitals or the bio-industry, where the coating can support to reduce risk of infection from one person or one animal to the other and as such prevent the development of plagues.	Low, increasing in specific areas

TABLE 2 Nanomaterials dominating the nanoproducts used in the furniture industry in 2012

Contribution to the product →	Scratch resistance	Easy-to-clean	Anti-graffiti	UV/light stability	Self-cleaning properties	Anti-microbial
Nanomaterial						
SiO_2	X	X	X			
TiO_2 /ZnO				X	X	X
CeO_2				X		
Ag						X
CuO						X

In 2012, the nanomaterials used in the different product groups for furniture (Table 1) are dominated by nano-SiO_2, nano-TiO_2 and nano-Ag. Table 2 summarizes the top 6 of nanomaterials that are most often encountered in different nanoproducts for furniture. Table 2 also provides an overview of the main functionalities they introduce in the product. These nanomaterials could in principle be added to almost every base-product. For example, it only requires relatively small modification of the nanomaterial to change from a solvent-based to a water-based coating, or from a wood-coating to a metal-coating. And it is a matter of concentration to change a water repellent coating to an easy-to-clean coating.

Examples of nanomaterials or -products can be found in various databases of products containing nanomaterials available on the market. Most of these databases aim at a public of consumers (i.e. Woodrow Wilson institute[3], Nanowerk[4], Nanodaten[5], Bund[6] and Nanodatabasen[7]). None of these addresses materials or products for furniture in particular. Apparently still a number of barriers have to be overcome before the market can make large scale use of MNMs.

3 http://www.nanotechproject.org/inventories/consumer/
4 www.nanowerk.com
5 www.nanodaten.de
6 http://bund.net/nanodatenbank
7 www.nano.taenk.dk

LIMITING FACTORS FOR NANOMATERIAL USES IN FURNITURE

Though the potentials of MNMs for furniture may be promising, a large scale introduction of nanomaterials in furniture products is being hampered by a number of barriers. The most important factors that limit application at this moment in time are summarised below.

COSTS VERSUS BENEFITS

Most MNMs are relatively new substances. Their yearly production volumes are still low and their costs consequently high. As a result, MNMs are often found too expensive as a substitute for existing alternatives. However, this situation is changing as production volumes do gradually rise. Nano-TiO_2 is an example of a MNM that has just reached the point of becoming cost effective as UV-blocker in coatings.

LONG TERM PERFORMANCE

Because of their novelty, many MNMs still have to prove their long-term durability. Conventional production processes might have to be adapted and manufacturers and consumers both have to trust their performance in order for manufacturers to make investments in this new technique. As a result, MNMs are predominantly used in coatings. With growing experience and confidence though, MNMs can be expected to find their way into more complex, demanding materials. Nano-cellulose fibres are an example of a MNM that may be used in the near future to reinforce both coatings and composite material.

HEALTH AND SAFETY CONCERNS

Little is still known about health and safety aspects of individual MNMs. There is however enough reason to suspect more critical adverse effects compared to more coarse materials as a consequence of the small size and nano-specific reactivity of MNMs. Uncertainty on health and safety aspects of MNMs limits furniture manufacturers in using MNMs during manufacturing of the furniture. The uncertainty leads to concern about the health and safety of the workers, consumers and the environment. It also leads to concern about risks of exposure to MNMs and the appropriate control measures, during application and use and in the end-of-life. It is therefore essential that information on safe application and use of MNMs is communicated through the value chain of the furniture product: from the raw material manufacturer to the furniture manufacturer to the end-user(s) of the furniture product. Solid and trustworthy information from the supplier empowers the furniture employer to fulfil his obligations to protect the workers from risks associated with MNMs. When information on application and use is carefully communicated between the actors in the value chain of furniture, the furniture industry will be able to use MNMs in a safe way and to profit from the potentials provided by MNMs.

Polished surface of an MDF panel with a bamboo top-layer, treated with a high scratch resistant lacquer based on Nano-SiO_2.

HEALTH AND SAFETY CONSIDERATIONS

INTRODUCTION

Nanomaterials may behave more hazardous to humans than their micro-scale equivalents:

- Because they may penetrate the human tissue more easily;
- Because their powders may behave like gasses, which influences their migration and exposure profile;
- Because they may be transported via the nerve system, cross the placenta, or penetrate the skin
- Because their shape may induce specific toxicity responses like inflammation or oxidative stress;
- Because they have a larger surface to volume (or surface to mass) ratio, enhancing their chemical reactivity;
- Because they may show different chemical properties, like becoming catalytically active;
- Because they may show different physical properties, like electrical conductivity or enhanced solubility.

Even though current knowledge is still insufficient to predict toxicity based on the nanomaterials' composition and morphology, one can expect that the toxicity profile is at least partly related to the unique chemical and physical behaviour that makes them interesting for product innovation in the first place. However, regardless their intrinsic hazards, key to any health risk posed by nano-materials or products is the probability of exposure. When exposure is effectively prevented there will be no health risk.

ADVERSE HEALTH EFFECTS OF NANOMATERIALS

There is no general *"health effect of nanomaterials"*. Each nanomaterial will have its own unique adverse health effects. Of those MNMs found to dominate the nanoproducts currently used in furniture, only the toxicity of nano-TiO_2 is relatively well understood. In contrast, the toxicity of nano-SiO_2 and nano-Ag (nano-silver), the other two most often used MNMs, is much less well understood, and for all other MNMs, toxicity data are scarce or non-existent.

Because of the many unknowns regarding the adverse health effects of each individual nanomaterial it makes sense to collect what is known and to look for common trends. The health effects of nanomaterials observed most frequently are inflammation and oxidative stress. At a sufficient dose, inflammation and oxidative stress may lead to cell death or scar-tissue forming, for example in the lungs. Extraordinary cell growth, DNA damage and hormonal distortion are other effects that could result from these. A comprehensive review on the available knowledge on health and safety issues of nanomaterials is provided by Aschberger et al. (2011)[8]. These general health effects may eventually manifest themselves as inflammation of the airways, bronchitis, asthma, cardiovascular diseases, cancer or developmental effects on the offspring. Sensitization of exposed skin is also suggested as a possible adverse effect, for example in the case of surface reactive biocide MNMs like nano-TiO_2, nano-Ag, or nano-SiO_2 (see later). Current data are insufficient though to confirm sensitizing effects by MNMs.

ADVERSE EFFECTS OF NANO-TIO_2

In 2011, NIOSH (National Institute of Occupational Safety and Health) reviewed all scientific data available on the health and safety profile of nano-TiO_2. NIOSH[9] concluded that there is enough evidence to categorize nano-TiO_2 as a potential occupational carcinogenic substance. However, even more interestingly, NIOSH concludes that the carcinogenic effect observed for nano-TiO_2 is induced via a secondary mechanism, which means that this effect is not "chemical specific" but "particle specific", caused by the fact that nano-TiO_2 is non-soluble and nano-sized. A similar effect may therefore be expected for other non-soluble MNMs. NIOSH furthermore concluded that applying a thin coating around each nano-TiO_2 particle seems to enhance its carcinogenic potency and that the morphology (being amorphous or crystalline) did not seem to have a significant effect on the carcinogenicity.

ADVERSE EFFECTS OF NANO-SIO_2

Compared to nano-TiO_2, the toxicity profile of the second nanomaterial, nano-SiO_2, is yet much less well understood. Nano-SiO_2 can be produced in an amorphous or a crystalline form and in a large variety of shapes and morphologies. Depending on the exact structure, their physical and chemical reactivity is

[8] Aschberger A, Micheletti C, Sokull-KluttgenB and Christensen FM (2011) Analysis of currently available data for characterizing the risks of engineered nanomaterials to the environment and human health – Lessons learned from four case studies, *Environment International*, 37, 1143 – 1156

[9] Occupational Exposure to Titanium Dioxide, NIOSH, Current Intelligence Bulletin 63, April 2011

[10] Napiersky D, Thomassen LCJ, Lison D, Martens JA and Hoet PH (2010) The Nanosilica Hazard:another variable entity, Particle and Fibre Toxicology, 7, 39

different and their toxicity profile may be different as well. Napiersky et al. (2010)[10] reviewed the different forms and synthesis routes, described the available knowledge on the toxicity mechanisms at work. They conclude that the toxicity of nano-SiO_2 seems to be most strongly linked to its crystalline structure. Crystalline nano-SiO_2 is found to cause oxidative stress and consequently, DNA and membrane damage. In contrast, it is the amorphous form of nano-SiO_2 that is most often used by industry to improve product performance. The use in scratch resistant lacquers is an example thereof. The toxicity of amorphous nano-SiO_2 is considered much lower than that of crystalline nano-SiO_2 and consequently only a limited amount of studies did look further into its exact profile. The limited works available do suggest that nano-SiO_2 is not involved in progressive fibrosis in the lungs, but may result in acute pulmonary inflammation at high doses. Still, it might turn out that this picture should be nuanced, depending on the exact design of the amorphous nano-SiO_2. More and more studies become available that point at the strong interaction between nano-SiO_2 and peptides, the large effect of surface area on the reactivity of this nanomaterial and the dependence of toxicity on any surface modification. Interaction with peptides for example may hint an allergic potency (similar to epoxy-products), and important also, different studies do find different toxicities as a result of the use of different assays.

However, Napiersky et al. (2010) and references therein do suggest that the nano-typical health and safety risks for workers occur primarily when powders of the raw nanomaterial are produced or handled. In suspension or in a solid matrix, they state that nano-SiO_2 is fixed and that exposure through inhalation can be expected to be very low.

ADVERSE EFFECTS OF NANO-AG

The toxicity of silver has been studied intensively in the past, showing that silver is relatively non-toxic for humans but can be extremely toxic for the environmental organisms. In contrast to this macroscopic silver, the toxicity profile of nano-Ag is less well understood. In both cases, toxicity is determined by the emission of silver ions (Ag^+). However, in the case of nano-Ag, the nanoparticle itself may cause an increased toxicity as upon exposure it may show a different distribution in the human body (or in the environment) compared to the larger sized silver particles. For example, in environmental toxicity studies nano-Ag was observed to act as Ag^+-bomb in micro-organisms. An overview of the data available that describe the toxicity profile of nano-Ag is given in a recent study by TNO (2011)[11].

However, despite the current lack of a complete toxicity profile for nano-Ag, there are clear signs that prudence is called for when applying nano-Ag in furniture products. One of the essential applications of nano-Ag is for medical treatment of highly sensitive wounds, bacterial infections or as a disinfectant for bacterial strains that are very persistent and/or have become resistant towards other antibiotics. Misuse though, may contribute to the development of bacterial resistance to silver (see TNO 2011 and references therein), and when this happens this may have a huge effect on human health.

OCCUPATIONAL EXPOSURE LIMITS

To assess workplace safety, occupational exposure limits (OEL) are often used. Current scientific knowledge is too limited to propose health-based OELs for most nanomaterials. Only for a limited number of nanomaterials a health based OEL, recommended exposure limit (REL) or derived no-effect level (DNEL) are proposed by companies for their manufactured nanomaterials or by research organisations. Table 3 summarizes a selection.

As an alternative until solid health-based nano values are developed, provisional nano-reference values can be used as pragmatic benchmark levels. Different initiatives did look into the possibilities to construct a scheme to derive generic reference values for MNM, like the German IFA (Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung) and the British BSI (British Standard Institute). In the Netherlands, employers' and employees' associations mutually agreed to use such benchmark levels for occupational exposure: the so called provisional nano reference values (NRVs). In March 2012, a NRV scheme was published by the Dutch Economic Council (SER)[12] as an official advice to the Dutch Ministry of Social Affairs and Employment, shown in Table 4.

The derived NRVs are to be used as pragmatic benchmark levels – they do not guarantee that an exposure to nanomaterials below these values is safe. The NRVs may be used as long as the EU or the individual Member States have not tabled health based nano-OELs, or as long as specific Health-Based Recommended

[11] van Manen - Vernooij B, le Feber M, van Broekhuizen FA, van Broekhuizen P (2011) Pilot "Kennisdelen Nano in de verfketen", TNO Report V20123 | 1
[12] SER Advies 12/01, March 2012, Voorlopige nanoreferentiewaarden voor synthetische nanomaterialen, Annex 1

TABLE 3 Proposals for OELs, RELs and DNELs for specific nanoparticles

SUBSTANCE		OEL or REL mg/m^3	DNEL mg/m^3	Reference
MWCNT (Baytubes) *	8-hr TWA**	0.05		Pauluhn, 2010
MWCNT (Nanocyl)	8-hr TWA	0.0025		Nanocyl 2009
CNT (SWCNT and MWCNT) *	8-hr TWA	0.007		NIOSH 2010
Fullerene		0.8		NEDO-2 2009
Ag (18-19nm)	DNEL		0.098	Stone et al 2009
TiO_2 (10 -100nm) (REL) **	10hr/day, 40hr/week	0.3		NIOSH 2011

* CNT= Carbon Nanotube; SWCNT=single-wall CNT; MWCNT= multi-wall CNT
** REL = Recommended exposure limit; TWA = Time-weighted average

TABLE 4 The Dutch scheme of Preliminary Nano Reference Values (NRVs) as advised by the SER in March 2012

CLASS	DESCRIPTION	DENSITY (kg/m^3)	NRV (TWA 8h)	EXAMPLES
1	Rigid, biopersistent nanotubes, nanofibres and nanorods for which asbestos like effects are not excluded	-	0.01 fibres/cm^3 (= 10,000 fibres/m^3)	SWCNT, MWCNT or metal oxide fibres for which asbestos like effects are not excluded by the manufacturer.
2	Biopersistent, granular nanomaterials in the range of 1 to 100 nm	> 6.000	20,000 particles/cm^3	Ag, Au, CeO_2, CoO, Fe, Fe_xO_y, La, Pb, Sb_2O_5, SnO_2
3	Biopersistent, granular nanomaterials in the range of 1 to 100 nm	< 6.000	40,000 particles /cm^3	Al_2O_3, SiO_2, TiN, TiO_2, ZnO, nanoclay Carbon Black, C_{60}, dendrimers, polystyrene nanotubes, nanofibres and nanorods for which asbestos like effects are explicitly excluded
4	Non-biopersistent, granular nanomaterials in the range of 1 to 100 nm	-	Applicable OEL	e.g. fats, siloxanes, salt (=NaCl)

Occupational Exposure Limits (HBR-OELs) or Derived-No-Effect-Levels (DNELs) available from the REACH documentation are not available. The collaborative action between the Dutch social partners that resulted in the NRV scheme and its official status as SER advice make it unique among other approaches. Unique also is the metric defined: number of nanoparticles per cm^3, which expresses the current understanding that the reactivity of nanomaterials is related to surface area instead of mass. Application of the NRV scheme at European level is encouraged by the European Trade Union Confederation (ETUC) and the desirability of its application at the level of the European Union is currently being investigated. However, when used in a product a nanomaterial isn't necessarily an "unchangeable" particle. In many products the nanomaterial will react with or bind to the product matrix. Examples hereof are nano-silica in scratch resistant lacquers, nano-silver in high quality textiles or a nanomaterial used for electroplating. In other products, the nanomaterial remains more loosely embedded in the product matrix, like nano-titanium dioxide in self-cleaning coatings. The fate of a nanomaterial in a product influences its adverse health effects and the probability of exposure. It is therefore important to realize that its toxicity may change during its various life stages: from potentially hazardous as raw material to a non-toxic consumer product during use to hazardous waste again in the final phase or when spilled in the environment. Central in the health and safety debate on nanomaterials is therefore the question of fate:

What happens to the nanomaterial once it is applied and what happens to its nano-specific character?

EXPOSURE ROUTES

In the furniture industry, workers will be exposed (almost without exception) to nanoproducts (either in the form in which they are purchased or in forms which are developed due to use or processing) and not to pure nanomaterials, meaning that exposure occurs predominantly to:

Products in which nanoparticles (or nanomaterials) are embedded (in a solid matrix, in a powder, in a liquid or in a slurry), and to the dust or aerosols of these products produced when these are machined, sprayed or otherwise applied at the workplace.

This does have an impact on the actual exposure of the worker to the nanomaterial in the product. Work by Saber et al. (2011a[13],b[14]), does show that there might be a significant difference between exposure to pure nanomaterials and nanomaterials embedded in a coating. They studied different coatings (acrylic coatings and a UV-cured lacquer) doped with different nanomaterials (nano-TiO_2, nano-SiO_2, nano-Clay and Carbon Black) and found that the pure nanomaterials did show nano-specific inflammatory and DNA-damaging effects whereas, once embedded in the coating or lacquer, the toxicity profile of the sanding dust of these nanoproducts was similar to the toxicity of the same products without nanomaterials. In other words, first and preliminary scientific work does show that nanomaterials that are embedded in a matrix do not necessarily have to exhibit the nano-specific toxicity profile they present in their pure form. This is a very promising first result that is of high importance to the risk assessment of working with nanomaterials and products in the furniture industry and does encourage further study along these lines to determine if a similar effect is observed with other materials and products.

Generalizing the way in which a MNM can be part of the nanoproduct is three-fold:

1. A MNM may be chemically inert but able to physically interact. This results in a matrix in which the MNM is embedded but does not chemically react with the matrix of the product. In this way the nano-material remains "loose" and could in principle leach out.
2. A MNM may be chemically reactive. This results in chemical bonding between the MNM and the matrix, making it unlikely for the nanomaterial to leach out.
3. A MNM may be chemically and physically reactive and bind chemically at the surface of the matrix. In this way the nanomaterial is not likely to leach out but exposure may occur upon direct contact with the surface. Bactericidal surfaces are examples thereof.

In the following three subsections light is shed on the three different ways in which workers in the furniture industry might get exposed to nanomaterials from the products they work with. From the very nature of their daily activities and the products they typically work with, exposure through inhalation of nanomaterial dust (from cutting, sanding, drilling, sewing or machining) or aerosols from paint or glue-spraying are those most likely to dominate any health risks. Skin penetration may play a role as well (although much smaller), for instance with surface reactive substances such as bactericides one might foresee occupational health problems. Exposure through ingestion is also to be expected. Nanomaterials that are cleared from the lungs or nasal area will get ingested with the mucus, and chances are for example of ingesting nanomaterial containing dust or paint at lunch or coffee when hands and faces are not properly washed.

Exposure to nanoparticles by transporting solid furniture parts like nano-enhanced ceramics, glass, steel, plastics, composites, insulation materials, concrete, wood or surfaces treated with hardened coatings is expected to be very small due to the fact that in those cases the nanomaterials are expected to be contained in the solid matrix. It is nevertheless advisable to avoid skin contact also in these situations by wearing gloves in case of uncertainty.

EXPOSURE THROUGH INHALATION AND TYPICAL HEALTH CONSIDERATIONS

Exposure to nanomaterials through inhalation may occur when airborne particles are produced at the workplace, either because the processes involved produce dust or aerosols or because nanomaterial powders are handled. In the furniture industry, most nanomaterials enter the workplace as part (ingredient) of a nanoproduct like a coating or treated textile. The handling of raw nanomaterials was not observed in this particular project. Adding nano-silica based matting agents for coatings or lacquers and certain

[13] Saber AT, Jensen KA, Jacobsen NR, Birkedal R, Mikkelsen L, Moller P, Loft S, Wallin H and Vogel U (2011a) Inflamatory and genotoxic effects of nanoparticles designed for inclusion in paints and lacquers, *Nanotoxicology, Early Online,* 1 – 9

[14] Saber AT, Koponen IK, Jensen KA, Jacobsen NR, Mikkelsen L, Moller P, Loft S, Vogel U and Wallin H (2011b) Inflamatory and genotoxic effects of sanding dust generated from nanoparticle-containing paints and lacquers, *Nanotoxicology, Early Online,* 1 – 13

pigments (supplied in suspension), were seen in the industry.

Various studies have shown that nanoparticles can penetrate the lung tissue and reach the bloodstream. Nanoparticles may also be able to reach the brain via the nasal nerve system. There, they may cross the blood-brain barrier or be further transported through the nerve system. These two mechanisms could play a major role in the development of certain cardiac or central nervous system diseases.

Nanomaterials that deserve special attention are the tubular nanomaterials. Some years ago, carbon nanotubes got world-wide attention because of their suspected mesotheliomal effect (cancer of a specific part of the lung and peritoneum). Further study on this subject though, reveals that the toxicity of carbon nanotubes (and other nanotubes) does strongly depend on the exact shape and functionality of the nanomaterial. A comprehensive review on the current knowledge on this topic is provided by Zhao and Liu (2012)[15]. In a first precautionary approach it is nevertheless advisable to avoid all exposure to nanotubes, rods or fibres, unless asbestos-like effects are explicitly excluded by the manufacturer of the nanomaterial.

Tubular (or rod like) nanomaterials do deserve special care in the evaluation of health and safety of workers, consumers and the environment. The use of carbon nanotubes hasn't been observed in the furniture industry of today. However, given their unique electrical properties and their potential to act as reinforcing fibre, alternative flame retardant or algae-growth repellent, their future use could be foreseen.

EXPOSURE THROUGH THE SKIN

The skin is traditionally considered to be a good barrier against particles. However, when the skin is compromised (i.e. disrupted, damaged) or under stress (like on joints) nanoparticles may penetrate the skin. And also the hair follicles and pores are locations on the skin where penetration of nanoparticles may occur. Once a nanoparticle crosses the skin barrier, it should be clear that the underlying skin tissue and the bloodstream are its first two targets. Via the blood, the nanoparticle might get further transported to other organs. The skin itself can be the target organ too. To date, the development of skin sensitization as a consequence of MNM exposure hasn't been studied much. Given the functionality of some MNMs, designed for example to breakdown organic material or to act as biocide, a sensitizing potential cannot simply be excluded without further study. For nano-SiO_2, its reaction with peptides hints at a possible sensitizing potential that should be studied further. The skin as exposure route therefore deserves special attention in the furniture industry, for example when the work involves the generation of nanomaterial containing dust, or when nanomaterial containing dust residuals remain at the workplace.

EXPOSURE THROUGH INGESTION

Ingestion doesn't only involve nano-materials that are directly swallowed (through the mouth), but may concern as well nanoparticles that were inhaled and removed from the lung system with the mucus and consequently swallowed (called secondary ingestion). Nanoparticles can be absorbed in the intestine and enter the bloodstream like nutrients normally do.

EXPOSURE OF THE END USER

Even though the end user of a furniture product will most likely not actively be processing (manufacturing) the product, exposure to nanomaterials may be envisaged. Especially because there can be intense (skin) contact with the top-layer of the product (chair, table...). However, exposure will only occur if the nanomaterial is somehow "mobile", for example, like is the case with plasticizers, or if the nanomaterial is located at the top of the matrix as it is the case for bactericides. When assessing these risks for nanomaterial exposure though, one should realize that nanomaterials are often intended to be bound to or embedded in the material matrix. For this reason, exposure of the end-user will be low for many applications. Still the possible exposure of end-users should be a topic of careful consideration when designing the furniture product.

[15] Zhao X and Liu R (2012) Recent progress and perspectives on the toxicity of carbon nanotubes at organism, organ, cell, and biomacromolecule levels, Environment International, 40, 244–256

ORGANISING A SAFE WORKPLACE

WORKING WITH NANOMATERIALS in a responsible manner is outlined by the precautionary principle, advocated by the European Commission and the social partners of the furniture industry. The principle is no regulation but rather a principle of work consisting of 5 building blocks:

TABLE 5 Building blocks for a precautionary approach to working with nanomaterials (MNMs) in the furniture industry

1. When there is insufficient data available to determine the health and safety risks of MNMs, exposure of workers in the furniture industry should be prevented.
   - Avoid exposure to MNM according to the prevention strategy.
2. Because of the uncertainty on health and safety risks of MNMs, manufacturers and suppliers should notify their down-stream users in the furniture industry about the MNMs in their materials or products.
   - Declaration of MNM content of and possible release from a product or material through the production chain.
   - Notification of MNM content of and possible release from a product or material at a central register.
3. Exposure registration for the workplace allows for the early monitoring and retrospective examination of adverse health effects by MNMs on workers in the furniture industry.
   - Equivalent to registration of carcinogens: nano-fibres and carcinogenic, mutagenic, reprotoxic or sensitising MNMs.
   - Equivalent to registration of reprotoxic substances: all other non-soluble MNMs.
4. Transparent risk communication is essential for workers and employers to organise a safe workplace when working with MNMs in the furniture industry.
   - Information on MSDS (Material Safety Data Sheet) on known nano-risks, management and knowledge gaps
   - Information on safe application and use, for example in the form of an instruction manual
   - Demand a Chemical Safety Report (REACH) for substances >1 ton/year/company
5. Derivation of nano-OELs or use of nano reference values is required for assessing workplace safety.
   - For nanoparticles that might be released at the workplace.

To bring the precautionary approach into operation is complex. To support employers and workers in this process, various tools have been developed. One type of tool aims to assist workers and employers in assessing and evaluating the occupational health risk while working with MNM and to help them to install preventive measures to avoid or reduce exposure to a minimum. The Guidance on Working Safely with Nanomaterials and Nanoproducts, developed by the Dutch Social Partners, is an example of such a tool. Other tools focus on the derivation of Occupational Exposure Limits (OELs). Together, the Guidance and the NRV-scheme can be considered a good practice for organising a precautionary workplace. At EU level, in several other EU Member States and in the US, similar initiatives are in process.

WORKPLACE EXPOSURE SCENARIOS FOR THE FURNITURE INDUSTRY

Over the last years, more and more research has been published studying the possible exposure of workers to nanomaterials under real life conditions. Main focus of these studies is on the possible exposure during sanding or spraying activities and during working with nanomaterial powders. Preliminary findings do all point in the same direction concluding that exposure to free nanomaterials is only observed when working with pure nanomaterials or nanomaterial powders. Once a nanomaterial is embedded in a matrix, exposure to the pure nanomaterial is no longer observed. Instead, the exposure observed during sanding or spraying activities is typically seen to consist of the product matrix with the nanomaterial embedded in this matrix. The workplace exposure measurements conducted in the context of the present study are in line with these preliminary findings.

In a first approach, working with MNMs in furniture could be categorised in three risk "zones":

OF HIGHEST RISK are those activities in which powders of pure MNMs are handled. First actions to lower exposure should be:

(1) to investigate if substitution by an alternative product with known health and safety risks is an option;
(2) to ask your supplier to supply the MNMs in liquid or paste form;
(3) to prevent any exposure (by shielding the worker, by ventilation, preferably using a fume hood or by using robotic-arms in a fully closed and automated process, or by personal protection measures).

FIGURE 1. High pressure spraying in the spray cabin.
The air flow of the ventilation system is represented by the arrow:
green indicates low number of nanoparticles,
red indicates high number of nanoparticles.

OF MEDIUM RISK are activities performed with MNM-containing materials (liquids or solids) i.e. paints, lacquers, adhesives, composites or textiles. Spraying, sanding, polishing, cutting or otherwise machining MNM containing materials are examples of activities with a high risk of exposure that may readily occur in the furniture industry. In those cases, exposure to MNM-containing dust or aerosols can be expected and should be avoided. The first activities to control any risk of exposure should be:

(1) to prevent the production of dust or aerosols as much as possible by the application technique,
(2) to apply an effective ventilation system and
(3) to apply personal protection measures against inhalation or skin contact.

OF LOW RISK are activities like the handling of MNM-containing solid or liquids materials without any dust or aerosol production. Carrying a MNM-coated panel board or can of MNM-paint from location A to B is an example of such an activity. The MNM is contained in the matrix and will not easily migrate out upon touch. It is nevertheless advisable to avoid skin contact by wearing gloves, for example when transporting furniture products treated with bactericidal coatings that are surface reactive.

In case of high and medium risk activities with MNMs or MNM-containing materials, it is furthermore advisable to monitor the actual nanoparticle exposure of the worker(s) involved. This should preferably be done before and after organising additional exposure reducing measures, to check the effectiveness of the measures taken and the necessity for further exposure control measures.

Below, the main findings of the workplace exposure measurements conducted in the context of the present study are described. Workplace measurements were conducted using two time-resolved nanoparticle counters (NanoTracer, Philips Aerasense) that measured the amount of nanoparticles present in the air and their average particle diameter. The composition of the nanoparticles present in the air was analysed using a Scanning Electron Microscope combined with Energy Dispersive X-ray spectroscopy (SEM/EDX[16]). Different analysing techniques are available on the market for assessing workplace exposure to nanomaterials. For a thorough assessment it is important at least:

1. to quantify the exposure in amount of nanoparticles resulting from the work activity
2. to determine the chemical composition of these nanoparticles

The following cases are based upon short term observations. They only serve as inspiration for designing the preventive measures to be taken at the specific workplace.

Spraying of paints, lacquers or adhesives

When a nanoproduct is sprayed the inhalation of aerosols is potentially the most important exposure risk and for that reason spraying and working with dusty materials should be avoided when possible. Risks of exposure are smaller when using a brush or roller than when using a spray-pistol. Occupational exposures are also smaller when a spraying process is performed automatically in a closed environment by a robot arm than when the spraying is done manually.

OBSERVATION CASE 1: HIGH PRESSURE SPRAYING of a MNM-containing lacquer on wood panels was done in a spray-cabin shown in fig.1. No special measures were taken to prevent exposure to MNM, except from the normal protection against the high solvent lacquer. A large MNM-exposure gradient was observed, indicated by the arrow in Fig. 1. At the worker, MNM exposure was very low. Near the vacuum wall, concentrations measured were much higher. This observation suggests that a well-designed ventilation system is effective for removing MNM from the breathing zone of the worker. Yet, no health based nano-OEL is established for this MNM to assess the workers' exposure. Comparing this work activity with the NRV as an example of good practice, no further exposure control measures would have been strictly required. Nevertheless it is advised to wear the proper personal protection. Uncertainty still exists regarding long term adverse effects of sudden peak exposures or low doses that motivate avoiding MNM exposure whenever possible.

When there is a risk of exposure to MNM-aerosols or dust, it is important to equip the ventilation system with a HEPA filter, wear a respiratory mask designed with FFP3 filter, and glasses, nitrile gloves (preferably two pairs) and a Tyvek© (or similar non-woven) suit for skin protection.

OBSERVATION CASE 2: LOW PRESSURE SPRAYING OF A MNM-COATING was done with a manual pump-spray. The activity is shown in Fig.2. The spray was used to wet a wiping cloth with which the surface of a cushion was treated. The room was not ventilated. Spraying was applied at "hip-height". No MNM

[16]SEM/EDX Analyses were performed at the University of Utrecht (NL), Department of Electron Microscopy, under the assistance of JA Post and JW Geus.

exposure was detected. The present case suggests that careful low pressure pump-spraying may result in a low, non-detectable exposure, and that consequently, no additional exposure control measures are required to prevent MNM-inhalation. Skin protection should be applied.

Among other factors, exposure to MNMs depends on the actual behaviour of the worker during the activity with MNMs and the intensity and duration of the work. It is advised to always evaluate the effectiveness of the exposure control measures, preferably by quantitative and qualitative analysis.

FIGURE 2. Coating of a dentist chair cushion using a pump-spray and a soft wiping cloth.

Sanding and polishing of paints and lacquers

OBSERVATION CASE 3: SANDING OF WOOD PANELS TREATED WITH HIGH SCRATCH RESISTANT LACQUER.

During sanding, nanoparticles are being produced as a fraction of the total sanding dust produced. Nanoparticles are additionally formed by the engine of the sanding machine. Available data show that low energy sanding produces little nanoparticles. High energy sanding produces more nanoparticles. Available data do also suggest a similar emission of nanoparticles from coatings containing and coatings not containing nanomaterial additives. Work by Saber et al. (2011) furthermore suggests that sanding dust from nanomaterial containing paints may be similarly toxic as the sanding dust of the same non-nano paint. Given the current knowledge, no additional risk of exposure to the nanoparticles caused by fracturing/abrasion of surfaces treated with nanocoatings may therefore be assumed. However, depending on the matrix and the time that the inhaled ultra-fine particles remain in the lungs, the possibility remains that the matrix will dissolve in the lung fluid exposing the nanomaterials that were embedded in this matrix.

When one deals with a solid (non-dusty) nanoproduct, the probability of exposure to the nanomaterial ingredient depends on its interaction with the matrix it is contained in (or at). When the MNM is inert but able to physically interact, this results in a matrix in which the nano-material is embedded but not chemically bonded to the matrix. In this way the MNM remains "loose" and could principally leach out, increasing the risk of exposure upon touch. One could also envisage the MNM to be chemically bound to the surface and reactive, for example a bactericidal surface. Also in this case exposure to the MNM could lead to adverse effects. Only when the MNM is embedded and fixed inside the matrix, exposure is probably unlikely.

The sanding of wood panels of observation case 3 took place at a non-ventilated work bench. The sanding machine was equipped with local exhaust ventilation. MNM exposure was observed during dry sanding and during polishing. When these activities stopped exposure was quickly reduced. During wet-sanding activities no MNM-exposure could be measured. The present measurement suggests that dry sanding and polishing lead to MNM-exposure that may be higher than advised by the Dutch NRV scheme, especially when sanding takes a full working day. In this case, working in a non-ventilated environment isn't effective to control exposure and further exposure control measures should be installed. Examples of a vacuum ventilated work-table or wall and personal protection measures are shown in fig. 3.

FIGURE 3. Two examples of exposure control measures to prevent exposure to MNM while sanding or polishing MNM containing materials.
Left: a vacuum exhaust ventilation workbench;
right: optimum protection using nitril gloves, a Tyvek suit and respirator mask with FFP3 filter.

Also when the work is completed it remains important to avoid skin contact to MNM powders, dust or liquids. For example, when MNM containing dust is still sitting on the sanded panel. Never use pressurized air to clear this dust. When cleaning the workplace, an industrial vacuum cleaner with HEPA filter and wet wiping tissues should be used to prevent nanoparticles from spreading. The use of a broom, brush or household vacuum cleaner should be avoided. Spills, empty packaging, or leftovers should be labelled and removed as toxic chemical waste.

Cutting Textile

OBSERVATION CASE 4:
A NYLON TEXTILE treated with a water-repellent nanocoating is cut with normal scissors. No nanoparticle exposure could be detected. Special care should be taken to avoid possible exposure to nano-fibres. Even though no exposure to fibres containing MNM was detected, it is advisable to work in front of a vacuum wall or on a vacuum ventilated table when there is a risk of exposure to fibres containing MNMs.

Actual exposures do vary strongly depending on factors like the specific product, the exact environmental conditions and the concrete work situation of the worker(s) involved.

THE FOUR EXAMPLES for the activities in the furniture industry presented here should not be generalised to other similar work practices. For each new individual case a risk assessment should be undertaken to judge the effectiveness of the exposure control measures in place and identify which preventive measures to install in order to protect the health of the workers. These four observation cases however do suggest that the current exposure control measures prescribed for the furniture industry may well be effective to protect workers against exposure to MNM in the products they work with.

TRANSPARENT RISK COMMUNICATION AND TRACEABILITY

There is an enormous problem with the “sharing of information about nanomaterials” through the value chain of the product in which they are used, in the furniture industry, but also in many other sectors. In 2012, there is little transparency on the presence of MNMs in materials and products available for use in furniture. This is primarily because European legislation does not (yet) demand any nano-specific communication on MNMs present in materials or products, beyond the requirements set for all substances by the REACH regulation and the CLP directive. If and how this should be organised in the near future is currently being debated at European level.

Communication about MNMs in materials or products on a voluntary basis is of only little success. The most important reasons for a lack of communication highlighted by the different stakeholders of the furniture industry are summarized in this report. The chain of communication typically starts at the MNM-manufacturer, who informs the material manufacturer(s), who informs the supplier, who informs the furniture manufacturer. The furniture manufacturer informs its workers about the MNM used and down-stream users of the furniture produced. The supply chain of material manufacturers can be long. The chain of textiles for example, may consist of a fibre manufacturer delivering to a producer of yarn, who sells the yarn to a weaver. However, furniture production may also be a patchwork of different subcontractors assisting in the assembly of one furniture product. At each step further down the chain, more and more precious MNM-information tends to be lost.

In the communication from supplier to the furniture manufacturer, four factors dominate the lack of traceability of MNMs in materials. Competition and intellectual property rights are one, leading to secrecy. Marketing is second. For some materials “nanotechnology” sells. These are suggested to contain MNMs, but may appear to have none. For other materials this argument is less convincing. These are therefore often not “labelled” as nano. Only a select number of materials or products are correctly labelled and contain specific information on the MNMs. A third important reason limiting traceability of MNMs in materials is the social debate on uncertain health and safety aspects of MNMs. Instead of communicating about this uncertainty, uncertainty has become a reason for confidentiality in order to “not raise unnecessary questions”. The fourth factor limiting communication is ignorance. Material suppliers are often not well informed themselves and consequently can provide only little or no information to the furniture manufacturer.

The Furniture manufacturer has the responsibility for the health and safety of the workers. On top of this, the furniture manufacturer shall ensure that the products are safe for use. For the communication on MNMs, this implies:

1. getting informed (i.e. by the supplier or subcontractor);
2. organising a precautionary safe workplace and informing/ instructing the workers involved;
3. informing the down-stream users in an appropriate manner.

Furniture manufacturers do indicate that the uncertainty on health and safety currently often stops them from using MNMs for their products. On top of that, the question *how to act upon the MNM-information received* affects their desire to know and become informed on the MNMs they might use already. Some furniture manufacturers rather not know, because as soon as you know, what should you do? Others have already taken action, simply asking their suppliers and contractors to report back to them on the possible presence of MNMs in their products.

This situation deserves serious attention. It is advisable for furniture manufacturers to ask their suppliers whether or not their materials contain MNMs and get informed on how to apply them responsibly. At the same time, furniture manufacturers should be reassured that when they work with MNMs, they will be able to organise a safe, precautionary workplace. Various exposure control measures are available, like specific ventilation systems and personal protection equipment, and have proved to be effective for also preventing exposure to MNMs. Moreover, there are various tools available to support employers and workers in making a risk analysis, a risk assessment, including a plan for action for working safely with MNMs. Employers and workers should furthermore be informed that the nano-specific toxicity of MNMs depends on the risk of exposure. Embedded and fixed in a matrix, for example, MNMs may be used safely. However also when MNMs are fixed, exposure through direct contact with the surface of the material may give rise to adverse effects when the MNMs exhibit surface reactive properties, like for example some biocide coatings. The furniture industry should be encouraged to explore the conditions under which they may profit from the potential of MNMs for furniture innovation and in a responsible manner.

INITIATIVES OF REGULATION ON NANOMATERIALS AND NANOPRODUCTS

Like any other chemical substance, the registration, evaluation, authorization and restriction of nanomaterials are in principle regulated under REACH[17]. The European Commission report *Nanomaterials in REACH* (2008) provides an overview on how REACH impacts on the regulation of nanomaterials[18]. The other important regulation in place for normal substances and mixtures is the Chemical Labelling and Packaging regulation CLP[19]. Nanomaterials that fulfil the criteria for classification as hazardous under the CLP Regulation must be classified and labelled. The European Commission report *Regulation, Classification, Labelling and Packaging of nanomaterials under REACH and CLP* (2009) provides an overview of the impact of REACH and CLP on nanomaterials[20]. The need for further specification of these legislations for nanomaterials and the development of further guidance is currently under development.

A first concrete initiative of France to make the reporting of the use of nanomaterials in products obligatory, is initiated within the context of the French environmental legislation *Loi Grenelle*[21]. It is intended to enter into force as of 1 January 2013, reporting about all substances produced, imported or distributed from 2012 onwards. The regulation applies to Chemical products, biocides and substances with nanoparticle status (Article 1) when produced, imported or distributed in France for 100 grams or more per year. Other countries such as Italy, Germany and Belgium are also considering to develop some form of nanomaterial notification scheme to get a better insight in their national market.

[17] http://ec.europa.eu/enterprise/sectors/chemicals/reach/index_en.htm
[18] http://ec.europa.eu/enterprise/sectors/chemicals/files/reach/nanomaterials_en.pdf
[19] http://ec.europa.eu/enterprise/sectors/chemicals/classification/index_en.htm
[20] http://ec.europa.eu/enterprise/sectors/chemicals/files/reach/nanos_in_reach_and_clp_en.pdf
[21] http://www.nanonorma.org/

CONCLUDING REMARKS

IN DEPTH STUDY of the European furniture industry and interviews with furniture companies and material suppliers shows that the market for nanomaterial use in furniture products in 2012 is still in an early phase of development. Nanotechnology may have huge implications for the future of furniture manufacturing; on furniture quality and functionalities but also on environmental, occupational and public health performances related to the manufacturing and end-products. Bactericidal, water-repellent, high scratch resistant and UV protective coatings are examples hereof. Despite the many potentials for furniture innovation, major barriers are encountered with respect to costs, (long term) quality performance, uncertain health and safety issues and consumer acceptance. However, a number of successful market applications of nanomaterials were also observed. Examples thereof are liquid-glass based coatings to obtain high scratch resistance, water-repellence, anti-microbial or easy-to-clean effects, UV protective coatings, bactericidal and easy-to-clean textile and ultra high performance concrete.

The study of the European furniture industry furthermore shows a high level of ignorance. Furniture manufacturers are typically not well informed about the nanomaterials they may use and the information that is communicated is often difficult to interpret. This situation deserves serious attention. It is advisable for furniture manufacturers to ask their suppliers whether or not their materials contain nanomaterials and get informed on how to apply them responsibly.

Nanomaterials can be more toxic than their micron-sized equivalents and may show unexpected adverse health effects due to their nano-specific character, including cardiovascular diseases, inflammation of the lungs, effects on the central nerve system, cell death, scar-tissue forming (for example in the lungs), malfunctions in embryos and the development of cancer cells in affected tissue. At the same time, furniture manufacturers have to organise a precautionary safe workplace when they work with nanomaterials. There are various tools available to support employers and workers in making a risk assessment, including a plan for action for working safely with nanomaterials. Risks of exposure can typically be expected when nanomaterial-containing dust or aerosols are produced. The spraying of paints or adhesives, sanding of coated surfaces and polishing or sawing solid materials are examples of work activities where this could happen. Various exposure control measures available, like specific ventilation systems and personal protection equipment, have shown to be effective also for preventing exposure to nanomaterials. The automation of production processes, using robotic arms in a closed environment, is another method to avoid exposure of workers. Preliminary findings furthermore hint that nanomaterials embedded in dust may no longer exhibit their nano-specific toxicity. Low risk of exposure to nanomaterials is expected when workers touch these materials embedded and fixed in a matrix.

When exploring the potentials of MNMs, the furniture manufacturers shall set up precautionary preventive measures protecting the health of the workers – based on information delivered by the supplier of the MNMs, a risk assessment and the general principles for prevention associated with the actual chemical substances.