NanoDialogue

of the German Government

Opportunities and Risks of the Application of Nanotechnologies in the Construction Sector

Summary of discussion

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Content

1 Background

Since 2006, the German Ministry of the Environment, Nature Conservation, Building and Nuclear Safety has organised the German stakeholder dialogue on opportunities and risks from the use of nanotechnologies. The dialogue started in the frame of the NanoCommission, which was supported by topical working groups. Since 2011, the discussions have taken place in 2-day ExpertDialogues. In June 2015, the 5th dialogue phase started with a conference to reflect on the past 10 years of discussions and to collect topics for future debates. Among other topics, the use of nanomaterials in the construction sector was proposed and chosen for the first ExpertDialogue because of two main reasons: due to the large material flows, the construction sector has a high relevance for the environment and the competencies for the construction area were transferred to the ministry in December 2013.

2 Proceedings at the ExpertDialogue

The ExpertDialogue on “Opportunities and Risks from the Use of Nanotechnologies in the Construction Sector” consisted of five sessions:

- short inputs from the perspectives of different stakeholders,
- regulation of nanomaterials in construction products: presentation and discussion of the EU Construction Products Regulation (Reg. (EC) 305/2011), the pertaining standardisation procedures and the national authorisation process,
- overview of opportunities and risks: workers protection, environmental assessments and waste treatment of nano construction products,
- specific application areas: overview implemented or planned uses; benefits and assessment of possible risks from specific nano construction products and their different fields of application,
- outlook: research on the use of nanomaterials in the construction sector.

The presentations from the ExpertDialogue are available on the internet for download.

3 Requirements for construction products

3.1 European construction products regulation

Two presentations elucidated in detail the EU Construction Products Regulation, the pertaining framework of harmonised standards as well as the national authorisation process. Details on the regulation can be found in the background document and the presentations regulation on construction products und standardisation.

The presentations showed that the adaptation of the harmonised standards to the Construction Products Regulation's requirements with regard to environmental and health impacts only progresses slowly. This is indicated for example by the high number of standardisation mandates and harmonised product standards that has not yet been updated. The following findings in relation to the EU-wide regulation of nanomaterials in the context of the Construction Products Regulation evolved from the discussion:

- The Construction Products Regulation generally covers environmental and health concerns of (hazardous) nanomaterials in relation to the requirements on "safe buildings".
- However, no definition of nanomaterials and no particular requirements for nanomaterials are included in the regulatory text.
- The European list of hazardous substances, which may be contained in construction products and which should be considered in the standardisation work, does not contain any nanomaterials and does not differentiate between different sizes of substances. Therefore, product specific standards do not address (specific, potentially hazardous) nanomaterials.
- The horizontal standards on emission measurements of hazardous substances and on a unified terminology are not adapted to the specificities of nanomaterials.
- Nanomaterials are not sufficiently well identified and characterised in the context of registrations under REACH. Consequently, safety data sheets do not specify if a substance is included in nano form or not. Therefore, the actors in the construction sector (as well as other actors) do not receive information if the products they use as raw materials (substances, mixtures or articles) contain nanomaterials.
- The condition for considering (specific, hazardous) nanomaterials in the standardisation process is that respective requirements of buildings exist in at least one Member State and that the Member State notifies this to the EU with the aim of starting a related standardisation process. This situation has not occurred, i.e. no Member State has notified such a national requirement, yet.
- It takes several years from the time the EU Commission mandates a standardisation body and the publication of a product standard. Adaptations of existing or developments of new standards (that consider nanomaterials and

their potential impacts on human health and the environment), would therefore become effective with a respective delay.

3.2 National authorisation

The range of different construction products that can be submitted to a national authorisation according to building laws (German: allgemeine bauaufsichtliche Zulassung) was restricted by a decision of the European Court of Justice. Since then, only products, for which no EU harmonised requirements exist may be authorised at national level. [1] In Germany, the "Deutsche Institut für Bautechnik (DIBt)" is the national authorising body.

The DIBt's authorisation principles for environmental and health protection define the concept, the analytical methods and the testing programme for various construction products. As a precondition for market access, the producer, respectively the placer on the market of a construction product must present documentation of the product to the DIBt. The authorisation principles do not contain any criteria or requirements, which relate to (specific, hazardous) nanomaterials.

Currently, and from the product recipe, the DIBt can only partly identify the content of nanomaterials in construction products. They assess the environmental and health impacts in the authorisation process by using the AgBB scheme[2] and further evaluation aspects. The DIBt does not consider the disposal of construction products and potentially related risks in the assessment and authorisation decision because only those performance aspects that are relevant for the safety of buildings during their use phase may be used.

The discussion on regulatory aspects showed that it is challenging for "outsiders" to understand which products are covered by EU standards, which are nationally authorised and which may be placed on the market without assessment. In addition, it is not clear which material requirements standards and/or authorisations address. There is no list of EU product specifications with explanations on:

- The product types a standard covers and if exemptions from the scope exist[3];
- The actuality of product standards with regard to health and environmental requirements and when updates can be expected;

[1] Before the ruling of the Court of Justice, also products for which harmonised standards exist could be authorised at national level if these standards lacked requirements for the environment and human health or were insufficient in this regard.

[2] This is a scheme to measure volatile organic compounds from construction products via chamber tests, which has been developed by a dedicated German organisation.

[3] The standards' titles are not always clear enough to deduce, which types of products are covered.

- Which product types require a national authorisation which need no specific assessment at all.

A compilation of the above information would help all actors to understand the processes at EU level better (transparency) and enable their potential involvement in the development of standards. Furthermore, producers of construction products would gain certainty on how to design and test their products.

3.3 Responsibilities of the federal states

The German federal states define the requirements on the construction and safety of buildings in their building laws. Thereby regulating which construction products may be used. The building laws of the federal states are based on the provision of the "model building code" (Musterbauordnung, MBO).

The federal states are responsible for the implementation and enforcement of legislation, including market surveillance on the provisions of the EU Construction Products Regulation. According to statements by federal state representatives at the ExpertDialogue, enforcement authorities mainly assess if the CE-label is rightly attached to a construction product. The federal states would lack resources for a more thorough surveillance of construction products.

3.4 Overlaps with the Biocidal Products Regulation

Several participants at the ExpertDialogue noted that the interface between the EU Biocidal Products Regulation and the EU Construction Products Regulation is unclear. This became particularly evident in the discussions on antimicrobial surface coatings because it was not clear under which they are regulated.

It was explained that biocidal products according to the definition of the Biocidal Products Regulation would have to fulfil the related requirements in any case. An additional assessment of the human health and the environmental impacts could be omitted under the Construction Products Regulation. However, as the assessment of active substances in biocidal products is ongoing, it is possible that Biocidal Products are assessed (also) under the Construction Products Regulation with regard to their health and environmental impacts.

4 Possible benefits and risks from nano construction products

Various speakers introduced the potential benefits and risk from the use of nanomaterials in construction products. Different stakeholders emphasised that the assessment of construction products should always consider both aspects. They also felt that a political decision might be needed for specific applications if a potentially lower level of protection is justified by the potential benefits.

4.1 Environmental impacts

The largest positive environmental impacts from the use of nanomaterials in construction products were expected in potential material or energy savings as well as the possible substitution of hazardous substances.

Material could be saved, for example, if nanomaterials enhance or newly provide specific material qualities, such as persistence or tensile strength of concrete, which would enable the use of lower amounts as compared to conventional products. In addition, resource savings could arise from a nanomaterial-enabled prolonged product lifetime via reduced material use for maintenance or product replacement.

Energy savings could result from a reduced energy demand during the buildings' lifetime or during product application. Some examples are reduced heating needs due to the insulation materials with a lower heat conductivity or a reduced energy input for the application of a construction product, such as during the concrete hardening stage. A reduced energy use is directly related to reduced carbon dioxide emissions and hence lower greenhouse impacts.

The replacement or reduction of hazardous substances in construction products could realise, if a nanomaterial, which has no or less hazardous properties, can achieve the functionality, due to which they are used. In addition, (novel) nanomaterial containing materials could make the use of hazardous substances superfluous, e.g. because they do not need maintenance or cleaning. One example presented at the ExpertDialogue are surface coatings, where nanoscale silver replaces hazardous biocidal active substances.

Some nano construction products decompose air pollutants as they have photo catalytic properties, which is another type of benefit. Buildings would provide large surfaces to install these catalytic surfaces and could therefore create large effects. However, there are controversies about this type of benefit: it is unclear if and which metabolites the catalysis generates and if they are less (eco-)toxic than their precursors. Some actors doubt that the light intensity is sufficient for a measureable result and others question the relevance of the problem and see no need to apply such specific paints (bearing potential risks).

With regard to the potential environmental risks, various participants of the ExpertDialogue stressed that the available information on (long-term) effects of nanomaterials in the environment are (still) not sufficient for a conclusive assessment. In general, the outdoor use of large amounts of nano construction products would lead to a high potential exposure. However, the normally firm binding of nanomaterials into the product matrices would prevent (to a large extent) their release. Furthermore, due to aging processes it would be unclear, if and how nanomaterials change their structure in construction products inside buildings and in which form they would finally be emitted.

The research project “Nanohouse” assessed different environmental impacts of nanomaterials in façade paints. Among others, the researchers concluded that:

- The improvement of the environmental performance plays a subordinated role in the companies’ product development.
- Emissions of aged nanoparticles need to be assessed in order to develop a comprehensive and realistic risk assessment[4].
- No leaching of nanomaterials from the analysed façade paints could be measured[5].
- Small and medium-sized enterprises need support in presenting the product benefits.

4.2 Benefits and risks for workers

The benefits of nanomaterials in construction products for workers was not explicitly presented and discussed. Benefits could consist of a better usability of construction products (e.g. concrete additives) and the replacement of hazardous ingredients, which would result in lower risks at the workplaces and/or the possibility to use less personal protective equipment.

Two situations exist with regard to workers’ exposure:

- Nanomaterials are intentional ingredients of construction products.
- Nanomaterials are generated when (non-nanomaterial containing) construction products are applied, e.g. during demolition of concrete.

The evaluation of risks during the use of nano products requires considering whether or not nanomaterials are bound to the product matrix, e.g. within a coating, and how the products are used. For example, it is not likely that workers inhale nanomaterials when applying a coating manually. Analyses of sanding activities showed that nanomaterials were not released from the sanded lacquer but remained bound to the matrix.

[4] Aged products behave differently than freshly added ones.

[5] It should be noted that research results cannot be directly transferred to other construction products or nanomaterials.

According to current knowledge, the protection measures applied, due to other ingredients of construction products also cover the risks that could arise from the contained nanomaterials. However, this conclusion should be continuously reviewed to consider new nano products entering the market. Products of high concern could be those that include biopersistent, stiff nanofibers.

The construction sector consists mainly of small and medium sized enterprises and is comparatively labour intensive (many workers). Many of these companies do not sufficiently well employ protection measures for workers. Continuous information on potential workplace risks and how to avoid them is therefore an important task as well as the enforcement of the implementation of protection requirements for workers.

It was stated that, when implementing a comprehensive risk management related to (ultra) fine dusts, it would not be useful to limit the scope to nanomaterials according to the EU definition, i.e. to exclude particles larger than 100nm. This was underlined using the example of cement, which is not a nanomaterial according to the EU definition but, due to its high dustiness, is an important risk factor at work places.

4.3 Consumers

The participants of the ExpertDialogue discussed the benefits of nano construction products for consumers. They saw benefits in a potential reduction of energy uses (and related cost reductions) as well as the availability of new functionalities, which could increase convenience in private homes. For example, dimmable window glass enables a more flexible light and heat management in buildings. Further potential benefits were identified in relation to surface coatings, such as reduced air pollutant concentrations inside buildings via photocatalytic effects, the reduction of biological risks from biocidal effects of paints and the reduction of cleaning and maintenance activities through self-cleaning.

The only potential risks for consumers from the use of nano construction products concerned the potentially (more) toxic oxidation products from photo-catalytic surfaces. However, this could not be substantiated due to a lack of related information.

The use of nano construction products could lead to consumer exposure in case they directly apply them, e.g. during painting. This was not further discussed.

4.4 Communication of benefits

Several participants stated that the transparent and understandable presentation of benefits from construction products containing nanomaterials would be a very important condition for their acceptance in the market.

A complete and trustworthy picture of a product’s benefits would need to be based on a (quantified) lifecycle assessment as well as an analysis of the impacts inside the building with a view to the functionality of the nanomaterial. This would ensure that benefits from one lifecycle stage, such as energy savings during product use, would be related to potential risk or drawbacks in other phases, such as a higher energy need for the production of the nanomaterial. In addition, only this approach could ensure a fair assessment of long-lived products against short-lived ones.

Communication on benefits addresses three types of actors:

- architects and planners, who have to define which materials are to be used in a construction project;
- craftsmen, who are contracted for construction or renovation works and consult their contractors regarding the use of construction products;
- consumers who select products based on available information for their own building activities.

Each of the target groups needs information on the product benefits (and potential risks) at a different level of detail and with a different focus and form of presentation.

The assessment and communication of product benefits should also consider if the functionalities achieved by the nanomaterial is desirable from a societal perspective. For example, the participants agreed that the targeted use of antimicrobial coatings in hospitals is very useful, while some stakeholders did not find such surfaces necessary in private homes. In addition, preventive measures, such as methods from construction physics to avoid moulding should be used with highest priority. The assessment of a problem’s relevance would be useful to provide orientation to the users on the extent to which the use of a product would yield benefits.

4.5 The waste stage

Several stakeholders at the Expert Dialogue pointed out that there is a knowledge gap on the challenges from the disposal of (construction products used in) buildings.

A presentation on the recycling of carbon concrete showed that (potentially nano scale) dusts could be generated during the demolition of buildings and building parts when works with high energy input are conducted (e.g. drilling). The current analyses do not yet allow concluding on whether or not the particle sizes of materials without intentionally added nanomaterials significantly differ from those, where none are added.

Several participants voiced their concerns regarding the waste stage, which are based on a combination of different issues:

- the large amounts of construction products and potentially contained nanomaterials,
- the low level of transparency regarding the content of nanomaterials in construction products and the lack of documentation on which construction products are used in buildings,
- the lack of consideration of the waste stage in the authorisation and standardisation of construction products,
- the lack of knowledge of possible problems in the disposal of nanomaterial containing construction wastes.

The concerned participants saw a need for research and actions to avoid future problems and/or enable their targeted management.

5 Use areas and product examples

Currently, there is no transparency on the content of nanomaterials in construction products. The activities by BG BAU to develop a list of nanomaterial containing construction products showed that products advertised using the term “nano” do not always contain nanomaterials. Producers of construction products frequently avoid being related to nanomaterials as there still appears to be a respective stigmatisation in the market. Therefore, some producers do not use nanomaterials while others do not provide information on whether or not they use nanomaterials in their recipes.

Due to the targeted utilisation of the various specific effects and surfaces, nanomaterials are in manifold applications of construction products. Compared to the base materials they are used in (e.g. cement), nanomaterials are comparatively expensive. Therefore, the potential markets of nanomaterial containing construction products are estimated to be limited to nanomaterials which are used in low concentrations. Furthermore, products enabling relevant resource savings or achieving higher prices through better product qualities could gain acceptance on the market (e.g. surface coatings) as well as pilot applications.

At the Expert Dialogue, an overview on the specific properties of nanomaterials and nanostructures that are used to achieve particular functionalities of construction products was presented. Some examples of these are presented in the following summary.

In the area of cement, concrete and plaster, nanomaterials may be used as crystallisation nuclei in order to change the application properties of these materials, e.g. to accelerate hardening, increase density or decrease application temperatures. Nanomaterials are also used as rheological additives to adjust the viscosity. Aerogels are produced by extracting water/solvent from dissolved substances without destroying their structure in the liquid phase. This technology is used to produce insulation materials (low heat conductivity).
Nanomaterials may form colloidal structures that can be destroyed by shaking or shearing but reform when they are not moved. This phenomenon is used in supportive liquids, e.g. for the construction of tunnels or chutes. In this type of application, large amounts could be used.
Pyrogenic silica has rheological properties and is therefore used, for example in paints to avoid their de-mixing. Other uses include uses as a rinsing aid in construction products as well as in foodstuff.

At the ExpertDialogue five product examples were presented, which have specific properties or benefits due to their content of nanomaterials.

Due to the content of nano silica the presented ultra high performance concrete has a very high density. The silica is consumed during the hardening phase. The concrete has a longer lifetime and hardness than conventional concrete, which results in savings of material and energy. Risks from the use of nanomaterials could not be identified, because exposures only occur during the mixing (workers protection). The producer did not apply for a national authorisation because the related costs would not be justified by the expected market success of the product. Up to now, the concrete has been used for applications, which do not need an authorisation, such as construction of casings for machines or pontoons.

A façade and wall paint with antimicrobial activity due to the content of nano silver to avoid growth of bacteria, mould or algae on the surface of buildings was presented. The paint's benefits as compared to conventional products were stated to be a long persistence against growth of organisms[6], no use of preservatives, low use amount and a good environmental performance. Possible exposures could occur during paint application, but were regarded as negligible, if normal protection measures are applied. Contamination of the surface would reduce the paint's effectiveness. The speaker emphasised that the paints could not replace the restoration of damaged surfaces and should only be used, if the origin of the problem was removed.

[6] In contrast to conventional paints, which release the active substances and therefore loose effectiveness over time, the silver particles are firmly integrated into the paint matrix and are not released.

The second surface coating presented as an example was a photocatalytic wall paint for indoor use, which contains titanium dioxide nano particles that oxidise air pollutants and partly also microorganisms, like mould. Titanium dioxide was selected because it is very reactive, stable, non-toxic[7] and comparably economical. The particles are expected to emit only during paint production and therefore, no risks are expected for consumers and the environment. However, several participants critically remarked that it is unclear if the metabolites from the catalysis have toxic properties and therefore are a (new) risk factor.

In the discussion about both coatings, some participants doubted the need to apply such coatings.

The use of nano scale opacifiers to reduce the heat conductivity of insulation materials was presented as another product example. In experiments, a reduction of 50-90% of the conductivity of an insulation material attributed to radiation could be achieved, depending on the specific form of the opacifiers. Thinner insulation panels can be produced and used for facades, which could not be insulated using conventional materials. If used in conventional applications, these, more efficient insulation materials would result in energy and heat savings.

A further product example presented at the ExpertDialogue were windows that can be dimmed due to an electrochromic nanoparticle layer. The windows can replace external sun protection and have various advantages: they are not susceptible to wind, the sight through the window is possible also in bright sunshine and a reduced need for cooling on days with high amount of light and heat radiation. Finally, no construction for external shades is needed on the outside of the building. As the electrochromic layer is located between two glass layers of the window, exposure during the use phase can be excluded.

6 Research

The Ministry of Education and Research funds various projects on the development of construction products, which, among others, involve the use of nanomaterials in its research programme. The research programmes NanoTecture and HighTechMatBau included topics like the insulation materials, windows that can be regulated, light concrete, innovative asphalt, new materials for bridges, railways and road surfacing. In addition, an activity to scientifically accompany the transfer of technologies to the market was funded. Consequently, it can be expected that in the area of mineral

[7] There is a large number of studies on the toxicity of titanium dioxide, which can, however, not unambiguously interpreted and evaluated in a harmonised way.

construction materials as well as in the use of organic materials and fine chemistry further product innovations will be developed.

7 Conclusions

The presentations and discussions at the ExpertDialogue “Opportunities and Risks from the Use of Nanotechnologies in the Construction Sector” show that a broad spectrum of nanotechnology applications exist in the construction sector. This could result in benefits for the environment, such as energy and material savings and the substitution of hazardous substances. Benefits from consumers would be realised as improved quality of living in private homes. The use of nanotechnologies could lead to new or improved technical properties of construction products, which could open the way for totally new applications of construction materials.

Overall, the participants at the ExpertDialogue saw potential risks in the production and application of nano construction products, which could, however, be managed using conventional protection measures. As the nanomaterials, at least in the presented examples, are firmly bound to the product matrices, a release during the products’ use phase is neither intended nor likely. Therefore, few/no risks are expected for consumers and the environment from the products’ service life. There is a knowledge gap on potential risks from the disposal of e.g. buildings or road surfacing that contain nanomaterials. Therefore, some participants expressed a need for research in this context.

The regulation of construction products is complex and spread over various levels. Up to now, the particularities of nanomaterials have not been explicitly considered in the assessment of environmental and health impacts. An integration of respective requirements into the European standards is possible, but would require a longer process, which the Member States need to start. A stronger consideration of nanomaterials in national authorisations of construction products could be implemented in Germany via the principles for authorisation or the integration of specific requirements in the model building law, respectively.

For the further research and development of construction products, several stakeholders wish for more transparency on the benefits that are achieved through the use of nanomaterials. In addition, more transparency on the types and amounts of nanomaterials used in construction products would be needed. A comprehensive assessment and an understandable communication of benefits from nanomaterial-containing products as well as the potentially related risks from them, including from their disposal, was stated to be important for the acceptance of such products.