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SweNanoSafe

Swedish National Platform for Nanosafety

Nanomaterials in the construction industry – a life cycle perspective

SweNanoSafe – background description and workshop, 7 May 2019, Stockholm, Sweden

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Foreword

This report is based on a feasibility study entitled "Possible nationwide initiatives for safe utilisation, handling and development of nanomaterials in construction materials" by Danielle Freilich, completed in 2018 on assignment for SweNanoSafe. Klara Midander from SweNanoSafe wrote this report and planned the workshop on 7 May 2019, in collaboration with Ann Catrin Lagerkvist and Annika Hanberg. SweNanoSafe's steering committee and expert panel were contacted for comments.

SweNanoSafe

National Platform for Nanosafety

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Background

Sweden's built environment represents approximately 50% of national wealth, and the construction industry reports annual sales of approx. SEK 200 billion in construction investments (approx. 6% of GNP).[1,2] The industry represents an important sector for society with close links to economic growth and employment. The construction sector is principally local and national, even if the amount of international competition is on the increase. The Swedish market has more than 100,000 construction companies and the industry mainly comprises small companies (self-employed) with some larger enterprises (more than 500 employees).[3] The construction industry is material intensive and has substantial flows. The development and implementation of new materials in construction products is seen as a relatively rapid process, while in other regards the industry is perceived as conservative, facing challenges such as digitalisation, adaptation to the consequences of changes in demography and the transition to circular construction. One of Sweden's environmental quality objectives is to have "A Good Built Environment", for which interim targets have been specified, including the following: "Cities, towns and other built-up areas must provide a good, healthy living environment and contribute to a good regional and global environment." Nanomaterials are a group of relatively new materials with the potential for major utilisation in the construction sector. It is therefore important to ensure that these materials are used in a manner that is safe for human health and the environment.

About SweNanoSafe

The Swedish National Platform for Nanosafety, SweNanoSafe, was founded on assignment from the Swedish government in 2016 at the Swetox Research Centre. When Swetox closed at the end of 2018, the platform was moved to the Institute of Environmental Medicine (IMM) at Karolinska Institutet (KI). The platform is now managed by a steering committee with members from KI/IMM and the Swedish Chemicals Agency (KemI) (Chairwoman Marika Berglund, KI/IMM). The platform also has an expert panel comprising members with specialised expertise in various disciplines relating to nanosafety (Chairman Bengt Fadeel, KI/IMM), a research network, cooperation council with members from the authorities, businesses, academia and organisations (Chairwoman Annika Hanberg, KI/IMM) and a web portal for information, communication and collaboration (www.swenanosafe.se).

In the letter of appropriation issued by the Swedish Ministry of the Environment to KemI (Government decision 21.12.2018), Karolinska Institutet was awarded funds to *"further develop a platform for safe handling of nanomaterials that may help achieve the environmental quality objective for a non-toxic environment and to protect human health."* This assignment involves communicating and disseminating knowledge about the risks involved with nanomaterials to academia, the authorities, businesses and organisations, and to identify any obstacles to safe handling.

Purpose and objective of the workshop and report

During activities organised by SweNanoSafe and meetings of the expert panel and the cooperation council, the construction industry was highlighted at an early stage as an area of particular interest. This was agreed upon during work on the operational plan for SweNanoSafe in the new organisation, and a meeting on the issue of nanomaterials in the construction industry was planned for the spring of 2019.

On assignment for SweNanoSafe, Danielle Freilich, environmental consultant with many years of experience in the construction industry and one of the initiators of BASTA, (the construction sector's tool for phasing out hazardous components in products), had already prepared a feasibility study within the area. Based on this study, it was confirmed – including by SweNanoSafe's expert panel – that there was a need to review the knowledge status regarding nanosafety in the industry. Such a status description should also be supplemented by a needs assessment of necessary knowledge currently lacking in order to ensure sustainable and responsible handling of nanomaterials in construction products throughout their life cycle.

SweNanoSafe invited representatives from the authorities, businesses, academia and organisations to the workshop, all of whom in their different ways have knowledge of and an interest in utilising nanomaterials in the construction industry.

The purpose of the workshop was to jointly develop a status report for nanomaterials and nanosafety in the construction industry.

The objective of the workshop was to identify obstacles, including knowledge gaps, and to discuss the potential for safe development, application and handling of nanomaterials in the construction sector.

Feasibility study of nanomaterials in the construction industry

In a feasibility study of safe utilisation, handling and development of nanomaterials in construction products, Danielle Freilich summarises a number of European reports, describes the parties on the market and provides an overview of legislation, voluntary undertakings and reports. [4, 5, 7–10] This background description is provided below. Several other reports have been subsequently added.[6, 11–13]

THE OCCURRENCE OF AND EXPOSURE TO NANOPRODUCTS IN CONSTRUCTION MATERIALS

A number of studies have been conducted in recent years on the initiative of national authorities, academia and the European Commission (EC). The quality of the overviews varies; the scope of the studies varies; they may be based on surveys, extracts from national registers and/or market surveys.

One overview of the Austrian market in 2012 describes applications of nanotechnology in the construction industry.[4] Nanoproducts can primarily be found within four sectors: construction materials that contain cement-bonded material, sound reduction and thermal insulation, surface treatment to improve properties and fire protection.

A French report from 2015 describes the material of the future.[5] In relation to the construction sector, the authors confirm that knowledge, the number of products on the market and performance are currently limited. Information from the French nanoregister shows that the building and construction sector represents only 1.4% of declarations of nanomaterials in products. Nanomaterials are used in the construction sector as additives to materials such as concrete, asphalt, glass and plastic, and in surface treatment. The substances most commonly found are amorphous synthetic silica and titanium dioxide. The report is speculative and projects a rapid increase in the utilisation of nanotechnology in building and construction in order to improve material properties.

A UK report from 2017 presents a compilation of nanomaterials found on the market.[6] The report is based on information from manufacturers and interviews with suppliers and users. The most

common materials (containing nanomaterials) are concrete, glass and surface treatment/paint, in addition to insulation material and special steel. However, it is difficult to procure information on exactly what nanomaterials are being used and in which form. This makes it difficult to perform a risk assessment. The report also covers health hazards and, in this context, describes the status of knowledge about a number of specific nanomaterials (carbon nanotubes, graphene, carbon black, titanium dioxide, zinc oxide, silver, silicon dioxide/silica, etc.). Exposure, risk assessment and risk management are included. The report is pedagogically structured and highly informative. The results have also been published scientifically in abridged form.[7] Based on the UK report, the Institution of Occupational Safety and Health (IOSH) has produced a comprehensive guide for the construction and demolition industries: Nanotechnology in construction and demolition: Guidance for industry.[8]

A Swiss flow study of nanomaterials in paint shows that construction and demolition waste is a potential source of nanomaterials.[9] The study describes sources and flows of nanomaterials in paint and cement. The most commonly utilised nanomaterials in the Swiss construction industry are nano titanium dioxide, nano silicon oxide, nano zinc oxide and nanosilver. The study is a good example of a flow analysis for nanomaterials in construction.

The most comprehensive overview of nanomaterials in construction has been prepared by the EC's Directorate-General for Research and Innovation 2016.[10] The construction sector is widely defined as comprising building and construction production, installation and administration. The report contains a very comprehensive mapping of products and markets for nanomaterials in the construction sector. The report describes various regulations within the EU for nanomaterials in construction.

An early review of utilisation of nanomaterials in the construction sector (2009) was produced by the labour union organisations European Construction Industry Federation (FIEC) and European Federation of Building and Wood Workers (EFBWW), with support from the Commission (DG Employment). The complete report is based on a survey, in-depth interviews and a literature study. The abridged report summarises the results and contains specific descriptions of nanoproducts in the construction sector. It also describes exposure and provides proposals on how products and the working environment could be improved.[11]

Since 2006, the German government has conducted a series of dialogue meetings (NanoDialogue) with various stakeholders in nanotechnology and nanosafety. In this context, the construction sector was identified as a relevant subject for a so-called Expert Dialogue meeting (23–24 November 2016). The report summarises presentations and discussions regarding the various stakeholder perspectives, regulations/standardisation/approvals, opportunities and risks, existing and future applications, as well as ongoing research in the area.[12] As the regulations for nanomaterials in construction products are considered to be complex and hard to understand, the Expert Dialogue meeting was supplemented by a report that discussed and investigated how chemical legislation (REACH) and other European/national regulations for construction products interact with each other.[13]

PRINCIPAL UTILISATION OF NANOMATERIALS IN CONSTRUCTION PRODUCTS

The majority of nanoproducts can be found in many common construction products and construction materials, such as cement and concrete products, surface treatment and paint, insulation material and glass. Nanomaterials provide new properties to structures, such as self-cleaning, non-wetting, photocatalytic cleaning, fire protection, energy efficiency, improved strength, etc. The application of nanotechnology is limited to only a few specialised markets.

EXPOSURE

There are two principal exposure routes: firstly, during production/application of, for example, paint or additives in cement/concrete and, secondly, when handling nanoproducts during drilling, demolition, etc. In general, investigations into health hazards and environmental risks are of low quality and information is insufficient. However, to a certain extent it is possible to minimise health hazards by applying the knowledge available on safe handling and protective equipment for exposure to similar substances, e.g. dust and airborne particles, asbestos, etc.

PARTIES INVOLVED

Construction projects are generally performed by project organisations set up for individual projects. Many parties are involved in a construction project. For projects involving new buildings, maintenance and renovation, for example, the project organisation will comprise the building owner, real estate owner, architects, technical consultants, construction companies, wholesalers, retailers and construction material manufacturers.

The building owner is not the only party involved in a construction project to choose construction materials. Construction materials are also chosen by:

- construction material manufacturers who purchase materials and input components,
- wholesalers, import companies and construction material merchants who buy and sell construction materials,
- subcontractors who purchase materials mainly via wholesalers and, to a lesser extent, directly from material manufacturers,
- construction contractors who purchase materials via construction material merchants, wholesalers and directly from material manufacturers.

In particular, public enterprises that purchase large volumes of construction materials have the potential to make changes on the market and specify requirements.

Danielle Freilich concludes that, in general, the level of knowledge is low and fragmented. Suppliers may have information about the contents of nanomaterials, but this is not communicated to the end user. Moreover, the end user is seldom aware of how to apply such information in order to minimise any risks, etc.

LEGISLATION, VOLUNTARY UNDERTAKINGS AND REPORTS

The Construction Products Regulation lays down the conditions for marketing of construction products within the EU, in addition to the requirements on providing information about the contents of construction products. The purpose of the Regulation is to promote the EU's single market and free movement for construction products. EU member states are not permitted to issue national requirements for information about construction products that affect the conditions for sale. It is therefore not possible to achieve national regulation of the requirement to report additional contents in a construction product, as this is governed by EU law.

The provisions regarding protection of human health and the environment with regard to hazardous substances are found in the CLP and REACH regulations. At the time of writing, there are no requirements to report the total contents of construction products.

Construction product declarations represent a joint, voluntary system for the industry in Sweden to provide information on the environmental impact of construction products, and, to a certain extent, these include information on health hazards. The declarations represent a *standardised* basis for information on the health and environmental aspects of a construction product during different stages of the product's life cycle. This information shall, for example, provide assistance when choosing materials with a view to subsequent operation, management and demolition. If a construction product contains nanomaterials that have been added specifically to achieve a certain function, this shall be specified.

There are several systems for evaluating health and environmental information regarding construction products and for assessment of whether the products fulfil different requirements: BASTA, Byggvarubedömning and SundaHus. The systems provided by Byggvarubedömning and SundaHus require submission of a construction product declaration or similar, while BASTA permits suppliers to determine and specify whether the criteria have been met.

BASTA is a joint system for the industry, owned by IVL Swedish Environmental Research Institute and the Swedish Construction Federation, and its purpose is to phase out especially hazardous chemical substances in chemical products and construction products. With BASTA, chemical products and construction materials are required to have specifications regarding components and substances. The requirements in BASTA are based on the criteria for especially hazardous substances in the REACH regulations and the criteria of the CLP regulation. BASTA requires an annual audit with random testing of approx. 10% of the parties within the system. The auditors inspect whether, for example, an enterprise has procedures in place for producing information on chemical contents, and procedures and expertise for assessment of the chemical contents of construction products and construction materials.

Byggvarubedömningen (BVB) assesses construction materials partially based on criteria relating to chemical contents and partially on life cycle criteria. The focus during assessments is primarily on chemical contents, but life cycle criteria such as waste management and VOC (Volatile Organic Compounds) emissions are included.

SundaHus is a comprehensive system for assessing health hazards and environmental risks of products for the construction and real estate sector for new buildings, renovations and operations. SundaHus assesses products on a scale from A to D.

In June 2018, Boverket – the Swedish National Board of Housing, Building and Planning – issued a proposal for a logbook for construction products in construction work. The logbook provides a method for organising and archiving production information for the construction products used in construction work. One of the purposes of the logbook is to improve traceability for products used in construction, simplifying administration and material inventories during modifications, refurbishment or demolition. Thus, the logbook provides the premise for the sustainable utilisation of natural resources, minimises the spread of hazardous substances and promotes human health.

The Building Rules Modernisation Committee (Kommittén för modernare byggregler) has issued an interim report to the government regarding resource-efficient utilisation of construction materials.[14]

The committee was appointed by the Ministry of Enterprise and Innovation – up to 13 December 2019 – to review and modernise sections of the Swedish Planning and Building Act, sections of the Planning and Building Ordinance and the Swedish National Board of Housing, Building and Planning's (Boverket) Building Regulations. The interim report contains requirements for a list of contents for construction materials, including nanomaterials.

Extract from the Committee's proposal:

The Government should propose that the European Commission (the Commission) drafts a proposal to the Council of the European Union (the Council) and the European Parliament about requirements for lists of contents of construction products in Article 6.5 of the EU's Construction Products Regulation.

As a starting point, lists of contents of construction products should:

- *apply to all construction products covered by a harmonised standard or a European Technical Assessment, with the existing derogations stated in Articles 5 and 38 of the Construction Products Regulation,*
- *cover all components of construction products in the first place and, in the second place, substances according to Annex VI of the CLP regulation and the substances covered by existing requirements in Articles 31 and 33 of REACH, and*
- *specify the occurrence of nanomaterials in construction products.*

SweNanoSafe's further analysis of nine reports which, to a varying extent, relate to nanomaterials in the construction industry

As a supplement to Danielle Freilich's feasibility study, the in-depth reports were also analysed [4, 5, 7–10], in addition to those subsequently added [6, 11-13,] in order to identify what is primarily lacking. This initiative also provided a foundation for planning SweNanoSafe's workshop on nanomaterials in the construction industry and the formulation of issues.

The procedure was based on compiling information from the reports, allowing for the preparation of an overview and comparisons (in an Excel spreadsheet). The compilation of the reports comprised, for example, number of pages, number of references, headings in the table of contents and paragraphs of text that describe the reports' contents and conclusions. The analysis cannot be deemed complete but may be used to provide an overall perspective. The results of this analysis are presented below in a bulleted list.

What do these reports contain?

- General introduction to nanomaterials
- Description of special nanomaterials for utilisation in construction products (for example, silicon dioxide/silica, titanium dioxide, carbon nanotubes, graphene, copper, silver)
- Description of applications for nanomaterials in construction products (for example, cement and concrete products, paint and surface treatments, insulation and absorbent materials, steel and glass)
- Exposure during utilisation (exposure routes), health hazards in the working environment
- Risk assessment, regulation (based on current knowledge status)

What conclusions are presented in these reports?

- Nanomaterials have a huge potential for application in construction products

- At the time of writing, there is, in practice, no information on which products contain nanomaterials
- Awareness of possible exposure is generally low
- The actual utilisation of nanomaterials in construction products is currently thought to be very limited due to the high costs of such materials
- Risks relating to exposure have been identified during production and during construction work (when the materials are used).

What aspects of these reports are lacking?

- A life cycle perspective (a description of both the life cycle of nanomaterials in construction products and nanosafety in relation to the different stages of the life cycle)
- Environmental impact (overall environmental perspective)
- Quantified flows (methods for assessing subsets of nanomaterials in different types of bulk material)
- Discussion of the advantages/disadvantages (for example, environmental benefits resulting from a reduction in the volume of materials versus potential health hazards/environmental risks)
- Overview of research within the field (applications, environmental impact, climate impact (primarily greenhouse gases))
- Swedish/Nordic perspective

Planning and organisation of the workshop

The planning of SweNanoSafe's workshop for nanomaterials in the construction industry was based on many personal contacts with key persons in the construction industry, including the authorities, academia, businesses and organisations. Several persons have already participated in different SweNanoSafe's activities, including the expert panel and cooperation council. When they were contacted, these key persons suggested other relevant persons for the workshop, resulting in discussions and contact with additional persons. Based on the obvious interest, it was confirmed that the planned workshop would be an appropriate occasion to gather parties in the construction industry with a view to jointly preparing a description of the national status for utilisation of nanomaterials in the construction industry. Furthermore, the concept was to make use of this status report in order to identify areas in which knowledge must be procured and compiled. Plans were also made to allow the invited participants to collaborate – by jointly discussing and issuing proposals that could generate positive developments with a view to nanosafety in the construction industry. One important part of the meeting was a joint roundtable discussion during which all the participants had the opportunity to introduce themselves and their role/expertise, as well as their employer's interest in and approach to nanomaterials in the construction industry.

The final programme for the workshop revolved around group tasks, aimed at taking stock of the knowledge status and discussing challenges and obstacles for the safe utilisation and handling of nanomaterials in construction products/applications. The group activities were framed by three presentations that provided an insight into future applications of nanomaterials in construction products (Johan Liu, Chalmers), challenges when handling nanomaterials during recycling and waste management (Jenny Rissler, RISE) and how a major research project on nanosafety could contribute to the knowledge status in the construction industry (Tommy Cedervall, Lund

University).

Programme

9.30	COFFEE & REGISTRATION
10.00	SweNanoSafe welcomes the participants, followed by practical information and introduction to the programme for the day – Klara Midander and Annika Hanberg, SweNanoSafe
	1. Roundtable – brief presentation of participants
	2. Application of nanomaterials in the construction industry, future potential • Johan Liu, Chalmers Graphene in construction products – how is this eco-friendly?
12.30	LUNCH
13.30	**Continued 2. Application of nanomaterials in the construction industry, future potential** Group discussion Joint review
	3. Safety during production, construction, utilisation, recycling and waste management • Jenny Rissler, RISE, Lund University Handling nanomaterials during recycling and waste management • Tommy Cedervall, Lund University How could the Mistra Environmental Nanosafety project contribute to the knowledge status?
15.00	COFFEE BREAK
15.30	**Continued 3. Safety during production, construction, utilisation, recycling and waste management** Group discussion Joint review
	4. Final word – from all participants

Those who could not attend the workshop

During the work on planning, several parties were contacted via email and telephone and invited to take part in the workshop. Several stakeholders were unable to attend the actual meeting, but have contributed to the results in various ways, including providing status reports relating to utilisation of nanomaterials in construction products/applications, knowledge status and how their organisation worked on the issue, where applicable. This allowed interested parties who were unable to attend the meeting to provide feedback to the issues that were discussed at the meeting.

Summary of presentations and group discussions

The participants at the SweNanoSafe workshop for nanomaterials in the construction industry on 7 May 2019 comprised 23 representatives from the authorities, businesses, academia and organisations. They took part in a one-day meeting at Carolina Tower, Solna, with views of what is currently one of Sweden's largest construction workplaces, Nya Karolinska University Hospital and Hagastaden.

During the workshop, the participants worked in groups on various issues. The purpose of the questions was to map the current utilisation of nanomaterials in construction products and to identify obstacles for safe handling of nanomaterials in the construction industry.

Roundtable discussions

After SweNanoSafe had welcomed the participants to the workshop, a roundtable discussion was held during which all the participants introduced themselves. Each participant also provided a brief description of their employer's interests in or approach to nanomaterials in the construction industry, ref. table below.

Boverket (Swedish National Board of Housing, Building and Planning)	Boverket primarily has two perspectives regarding nanomaterials in the construction industry: • Exposure – for example, in connection with new buildings/renovations, but also in relation to issues involving the indoor environment • Technical properties – there is a knowledge gap in relation to construction products/materials, not least in terms of new products/materials, their advantages and disadvantages and potential risks.
Swedish Chemicals Agency (Kemikalieinspektionen)	Supported by the action plan for a "non-toxic working day" (2011–2020), the Swedish Chemicals Agency prioritises work within the nano area on, for example, risk assessments, developing legislation and policy instruments, developing test methods adapted to nanomaterials (OECD) and supervision. Independently and in collaboration with SweNanoSafe (the expert panel), the Swedish Chemicals Agency has acknowledged that the use of nanomaterials in the construction industry is an important area.
Swedish Environmental Protection Agency (Naturvårdsverket)	Nanomaterials are a growing issue and are being addressed in national waste plans. The presence of nanomaterials in waste flows is mentioned, for example, as an area for development.
Swedish Transport Administration (Trafikverket)	The Swedish Transport Administration is taking measures to prevent hazardous substances and materials to the greatest extent possible. It applies the BASTA

	criteria, which currently do not entail any general requirements for nanomaterials.
Centrum för arbets- och miljömedicin (CAMM, SLL (centre for occupational and environmental medicine))	Activities at CAMM mainly involve working with patients, but also risk assessments and exposure studies. Projects are conducted regarding measurement of quartz dust, for example, although more knowledge is required regarding nanoparticles.
SundaHus	SundaHus aims to seek new knowledge regarding nanomaterials in the industry by conducting environmental assessments of construction products.
Svanen (Nordic Swan Ecolabel)	Svanen is neither for or against nanomaterials, as these entail both challenges and opportunities. Nonetheless, Svanen abides by a precautionary principle and applies restrictions based on the information available. It receives numerous questions from the construction industry. Svanen has more than 60 criteria documents and, at times. These have, at times, somewhat different approaches to nanomaterials. Exemptions are permitted in cases in which documentation is good and shows that the materials are "safe"/risk versus benefit.
IVL Svenska Miljöinstitutet (IVL Swedish Environmental Research Institute) / BASTA	IVL provides expert support to enterprises/organisations within the field of the working environment, which also includes working environment, external environment, chemical hazards and air quality. The IVL is interested in nanomaterials in construction products as it is in charge of BASTA – the industry's environmental assessment system, which aims to phase out substances from building and construction products that have hazardous chemical properties. For BASTA, it is challenging to provide relevant information that offers safe guidelines. "Nano" is a complex group and not all nanomaterials have the same properties. This leads to a risk of incorrect product selection.
Swedish Construction Federation (Sveriges Byggindustrier)	Coordinates responsibility for resource and waste management and requires information on nanomaterials and where these are found. Such information makes it easier for the construction contractor to "do the right thing" and work safely. Environmental assessment systems are important for companies; they require good support.
Svenska Byggnadsarbetareförbundet	Byggnads' assignment is to provide information to its members and employers regarding risks in the industry.

(Byggnads) or the Swedish Building Workers' Union	Nanoparticles in construction products may represent a future risk, for example, during production of cast concrete and mixes. What are the risks associated with nanomaterials? What are the advantages of nanomaterials?
IF Metall	IF Metall is a labour union working for members' interests across large parts of Swedish industry, including plastics, pharmaceuticals, construction components, steel, chemicals and engineering. This includes working environment and chemical health hazards. Health-related issues regarding the use of nanomaterials in the construction industry are of interest to many members.
RISE	RISE carries out research into nanomaterials within waste management and life cycle analyses, in addition to research into applications, properties and impact within several areas of relevance to the construction industry, for example, cement-based surface protection, insulation and flame retardants.
Chalmers	Chalmers has overseen coordination of the EU's work on graphene for several years. Applications that could potentially be utilised in the construction industry are, for example, graphene-reinforced cement and graphene as an additive in surface treatments for cement and concrete surfaces. Research is conducted on how material properties – such as in cement, in contact with graphene – are affected at both a nano level and other sizes.
KTH Royal Institute of Technology (KTH)	Interdisciplinary research into the importance of material properties, for example, nanomaterials with regard to health outcomes and consequences for the environment. In relation to applications for the construction industry, KTH is participating in a research project on environmental aspects for metallic surfaces, as well as corrosion.
Lund University	Research into, for example, the environmental impact of nanomaterials and nanoplastics, coordination of research project, Mistra Environmental Nanosafety. Research and education in environmental law.

Presentations

Johan Liu, Professor at the Division of Microtechnology and Nanoscience, Chalmers, introduced the second part of the workshop, *Applications of nanomaterials in the construction industry, future potential"* with a presentation on graphene in construction products. Johan described current production techniques for large volumes of graphene, providing lower prices and opening the door to potential areas of large-scale application, such as graphene-reinforced cement. Graphene in cement is chemically bonded, via graphene oxide, to quartz. The material's properties in various applications have been studied in several research projects. The results indicate that graphene in chemically bonded form increases the performance of concrete and concrete paint. However, we currently lack knowledge of the risks and long-term impact of graphene in cement/concrete.

During the third part of the workshop, *"Safety during production, construction, utilisation, recycling and waste management"*, Jenny Rissler, Associate Professor and researcher at RISE and Lund University, held a presentation on handling nanomaterials during recycling and waste management. Jenny provided an overview of the different stages of the life cycle in which there is a risk of exposure to nanomaterials in waste. In practice, waste is present in all stages of a life cycle (manufacturing, processing, utilisation/consumption and scrapped products). Thus, consumers/workers and the environment and ecosystem are at risk of exposure to varying degrees. Waste from the construction industry may vary (demolition waste/sorted construction waste) and the method of waste management (recycling, incineration, landfill, water purification) has an impact on both risk and exposure.

Tommy Cedervall, lecturer at the Department of Biochemistry and Structural Biology and NanoLund at Lund University, explained how the Mistra Environmental Nanosafety project could provide knowledge of *nanosafety during production, construction, utilisation, recycling and waste management*. The programme will continue to study environmental risks caused by nanomaterials and how they may affect humans and the environment. The focus is on manufactured nanomaterials (used in coatings in the construction industry, for example) and how these change in the environment in which they are used or ultimately end up. At the time of writing, the knowledge status is poor, and the project aims to create strategies for how to deal with factors relating to the potential impact of converted nanomaterials when performing risk assessments. For more detailed information (in Swedish), see https://www.lu.se/article/nationellt-nano-projekt-flyttar-till-lund.

Applications for nanomaterials in the construction industry

The participants were initially given time to consider this issue and respond to three questions: *i)* whether they had ever come into contact with/know of a construction product that contained nanomaterials, *ii)* the advantages of using nanomaterials/nanotechnology in the construction industry, and *iii)* potential obstacles to utilising nanomaterials/nanoproducts in large-scale construction applications. These questions were then discussed in the groups and the groups' conclusions were presented in a joint review. Please note, the description of the group discussions below has not been examined for factual basis. The groups' responses can be seen as an inventory of knowledge and understanding of the use of nanomaterials in construction products. The workshop participants possessed a wide range of prior knowledge: experience of working with nanomaterials in products or researching various applications, to purely theoretical (limited) contact with such materials/products.

HAVE YOU IN ANY WAY BEEN IN CONTACT WITH OR KNOW OF A CONSTRUCTION PRODUCT THAT CONTAINS NANOMATERIALS? (IF SO, WHICH PRODUCT(S) AND IN WHICH CONTEXT?)

General applications of nanomaterials in the construction products that were addressed were:

- in paint and lacquer, in addition to joint filler, such as pigment in paints (silicon oxide/silica, titanium oxide), façade and roof paints, screed,
- in different types of surface coatings, e.g. dirt-repellent (windows), self-cleaning (graffiti prevention), antibacterial (nanosilver), reactive coating in road tunnels to minimise nitrogen oxides,
- as functional additives to other materials, such as cement, concrete, polymers, plastic and rubber (carbon black), laminate (as pigment).

In addition, more specific applications were mentioned, such as the use of nanoparticles in ventilation devices (dust prevention), materials for solar cells, aerogels/spray foam insulation, fire sealant foam and other fire protection materials.

WHAT ADVANTAGES DO YOU ENVISAGE WITH USING NANOMATERIALS/NANOTECHNOLOGY IN THE CONSTRUCTION INDUSTRY?

This issue was partially included to create a positive perspective to be compared with the safety aspects of using nanomaterials in the construction industry. The group discussions primarily confirmed the different functions and properties of nanomaterials. Utilisation in the construction industry implied, for example, stronger, more solid and durable materials which, by extension, would result in reduced material consumption. Lower weight provides lighter structures. The use of nanomaterials could potentially permit the replacement of hazardous substances used in conventional products, such as for cleaning. In summary, it was confirmed that the use of nanomaterials in construction products could imply a relatively lower climate impact with a reduction in material flow (lower energy consumption during production and transport), reduced maintenance and a longer life cycle, etc.

WHAT ARE THE CURRENT OBSTACLES TO LARGE-SCALE UTILISATION OF NEW APPLICATIONS OF NANOMATERIALS IN CONSTRUCTION PRODUCTS?

The groups discussed obstacles in relation to the positive consequences of increased use of nanomaterials in the construction industry. In addition to the obvious practical obstacles for large-scale utilisation – production solutions that provide access to raw materials at low costs – a number of other obstacles were identified, primarily relating to knowledge gaps, risk management and communication of knowledge, risks, nanocontent of products – in order to address current uncertainty and concerns.

Knowledge gap:

Knowledge is lacking of the properties of nanomaterials and how these materials may change throughout their life cycle

Knowledge related to life cycle is also lacking in terms of applications in the construction industry (particularly for waste and destruction)

Knowledge is lacking on the impact on humans/the environment (research on the impacts and risks for humans/the environment is required and should be included in research on applications)

Risk management:

Knowledge is lacking on the risk to humans/the environment (data and guidelines for correct risk assessments)

Requirements/regulations are lacking (quality requirements, standards, approval, application of legislation, effective supervision process)

Communication and information:
Information is lacking on the utilisation of nanomaterials (when a house is about to be demolished, how do you know whether the construction materials contain nanomaterials?)
Adequate communication is lacking (addressing concerns about health and the environment at different levels, acceptance, uncertainty as to whether the materials are safe)
Education/expertise in nanosafety is lacking (uncertainty due to lack of knowledge, alternatively full steam ahead – unaware of the hazard)

Safety during production, construction, utilisation, recycling and waste management

During the joint discussions, the groups were able to discuss the challenges/obstacles regarding safe handling of nanomaterials in construction products and jointly provide proposals for how these obstacles could be removed. The final issue regarding risk versus benefit was included in order to highlight this aspect when it comes to applications of nanomaterials in construction products of socio-economic and environmental interest.

The groups' responses are summarised in a bulleted list under the respective issues below.

WHAT ARE THE GREATEST CHALLENGES FOR SAFE HANDLING OF NANOMATERIALS IN CONSTRUCTION PRODUCTS WHEN IT COMES TO THE ENVIRONMENT AND HEALTH?

This issue overlaps with the previous issue regarding obstacles to increased utilisation. In this context, it appeared very difficult to discuss obstacles to increased use of nanomaterials in the construction sector without discussing obstacles to safe handling. The results from the group discussions can be summarised into the following general obstacles:

- insufficient information and knowledge of, for example, occurrence, conditions/properties, (eco)toxicity, exposure, traceability, lack of analysis methods
- uncertainty/lack of knowledge of risks in the working environment, which working methods involve risk, the appropriate protective equipment, it is not only manufactured nanomaterials that are of relevance to the working environment
- unsuitable criteria/assessment methods, inconsistent and overlapping rules/collaboration between authorities and stakeholders, ineffective supervision
- lack of communication/dialogue/knowledge exchange, understandable and manageable information on all risks (categorising substances/products as hazardous/non-hazardous)

IDENTIFY ANY OF THESE CHALLENGES AND PROVIDE PROPOSALS FOR HOW TO DEAL WITH THEM.

As a follow-on question, the groups discussed how to bridge these obstacles. The responses can be summarised as follows:

- Systematic work to chart/identify obstacles and needs (i.e. as performed in the workshop)
- Education and information (manageable and understandable for the user)
- Labelling of products with general hazard symbols and information on substances in nano form
- Produce information and guidelines for "nano-exposed" work

- Via a (new) documentation system, identify nanoproducts that are in-built
- Demand and make requirements for nano-specific information during procurement
- Create a harmonised nomenclature and categorisation of nanomaterials

DO YOU HAVE ANY EXAMPLES OF RISK VERSUS BENEFIT BEING PARTIALLY COUNTERACTIVE?

Discussions of risk versus benefit are socially relevant and the participants discussed which positions of this nature they had encountered.

- Utilisation of nano silver that can result in increased antibiotic resistance
- A low level of knowledge and lack of interest in obtaining information increase the risk of making incorrect decisions
- Self-cleaning surfaces – less need for cleaning/cleaning agents
- When processing applications for especially hazardous substances, risk and benefit are assessed in relation to each other
- The introduction of mandatory limit values for exposure represents a major cost

Conclusion in summary

Despite the special conditions in the construction industry, the potential for safe handling of nanomaterials in the industry is generally the same as for the field in general, and with the challenge of "promoting nanosafety in all aspects of the life cycle". The difficulties lie in the lack of knowledge and knowledge exchange, lack of information and documentation (e.g. non-transparent use of products). Nanosafety is of particular importance to the working environment, both during construction, as well as during demolition, deconstruction and recycling and waste management.

The premises can be affected positively by introducing clearer requirements and guidelines. The industry's own system for documentation and organisations for environmental labelling and certification provide the opportunity to take a leading position. However, knowledge is necessary in order to handle the requested information.

In relation to the working environment, both regulations and protection equipment exist with the capacity to protect workers (even in the case of hazardous exposure, for example, nanomaterials that generate dust). These are conditional upon compliance with legislation and correct and consistent use of protective equipment. If adequate protection is to be provided, constant efforts are required regarding the working environment, as well as effective supervision. During the workshop discussions, it emerged that the supervisory process in this context was not effective because of the lack of knowledge required to handle risk in the event of hazardous exposure to nanomaterials. During daily operations on a construction site, "nano" concerns should result in an increased awareness of occupational exposure to chemical health hazards in general, which is positive.

Even though the lack of knowledge represents an obstacle to safe handling of nanomaterials, a lot of information and data is available. However, this situation will only improve when this information is managed, so that knowledge of nanosafety can be exchanged at different levels. As such, the information needs to be adapted and distributed to different recipients, for example, specific information to construction workers.

Proposed initiatives

Below is a presentation of a number of proposed initiatives to help increase nanosafety in the construction industry. The proposals have been formulated by SweNanoSafe based on the workshop discussions with participants, persons in the industry or related to the industry. The proposals have not been ranked or sorted and, thus far, there have been no discussions as to who could carry out the initiatives – and when.

A knowledge overview of national/Nordic conditions for utilisation of nanomaterials in the construction industry is currently required and would supplement reports previously published in this area .[4-13] Below is a description of a number of specific areas in which knowledge and information must be compiled or produced, and which can be presented individually or form part of a total overview.

- In what is perhaps the most comprehensive compilation from the EC (NanoData Landscape Compilation Construction),[10] Sweden is described as a relatively successful nation in terms of research funds. It is also stated that Swedish companies invest in research and development in nanotechnology with applications in the construction sector. It would be interesting to study what this actually means for the use of nanomaterials in the construction industry. Thus, as a starting point for a knowledge overview, it has been proposed that all national research projects that target applications within the construction industry are compiled using the national research-funded project databases. A similar initiative for EU-funded research projects could also be included in this compilation.
- During the workshop, several parties including Skanska, engaged in dialogue about their attitude towards issues involving utilisation of nanomaterials and nanosafety. It would also be useful to interview representatives of the other major construction companies, as well as extend this initiative to cover medium-sized and small companies. As a follow-up to the workshop and as part of a national status report, it has been proposed to prepare an inventory of the use and handling of nanomaterials, as well as knowledge and knowledge gaps in nanosafety in construction companies. For example, this status report could be based on questionnaires and interviews/conversations with company representatives who have knowledge of the industry.
- The main areas of application for nanomaterials in construction materials and construction products have been generally described in a number of reports. However, there is a lack of detailed knowledge about the scope of actual utilisation, as well as which nanomaterials and products are involved in practice. The use of nanomaterials in construction materials and construction products probably differs across the different EU member states. Thus, a proposal has been made to produce knowledge of utilisation from a Swedish/Nordic perspective. This could be based on information available about the use of commonly occurring products (selection based on, for example, sales statistics and/or frequency in documentation systems) used for further analysis of the products' components.
- Fire protection is a specialised market and nanomaterials are used/expected to be used in this area. This is also of relevance to stakeholders in the construction industry. There is a significant lack of information on the utilisation of nanomaterials for fire protection and in

fire safety (construction) materials. A proposal has therefore been made for a status inventory from a Swedish/Nordic perspective and starting with literature studies, dialogue with the Swedish Civil Contingencies Agency (MSB) and contacts with companies in the industry.

- During the workshop, the participants discussed the working environment and handling of nanomaterials at construction sites. These discussions showed that knowledge of nanosafety is often lacking and that the situation could be improved by distributing customised information to different recipients (employers and employees). This type of information must be produced. Thus, one specific proposal is to produce customised information. This could be a brochure for employees who handle nanomaterials, on-site information about the risks of specific working methods, or online training modules. The information must be customised and communicated in different ways and at different levels, for example, by means of pictograms, brief texts, films or more detailed information and guidelines.

In addition to the proposals described above relating to knowledge status, a further initiative has been proposed based on a collaboration that aims to "simplify matters for those organisations that plan to 'be at the forefront' in terms of nanosafety". By virtue of their operations, organisations involved in, for example, environmental labelling and certification or systems for construction documentation have the opportunity to influence developments and take the lead by making requirements. At the same time, this information requires management. Thus, one proposal is to gather all expertise that could assist organisations involved in environmental labelling and certification or systems for construction documentation into one network/working meeting. In collaboration with research and regulatory expertise, requirements specifications and guidelines for management of the requested information could be produced in order to ensure safety during handling of these materials during production, construction, utilisation, recycling and waste management, as well as prevent a conservative approach. One initiative could be to explain how the new nano-specific appendices to the EU's REACH regulations relate to the Construction Products Regulation.

Finally, a proposal was also made to highlight the general knowledge gap regarding the use of nanomaterials in different applications in general and in the construction industry in particular, i.e. the lack of quantitative information on utilisation and material flows throughout the life cycle. It has therefore been proposed that such information is produced by means of a study comprising flow analyses based on proxy information such as production and sales statistics (or other indicators of utilisation) such as in a Swiss study [9], or following a different economic model. Several procedures may be required to produce relevant information. One example of such a procedure is the compilation of quantities and costs for major projects, based on interviews and materials in procurement processes. There may also be parameters involved in a construction project that could be monitored in order to identify flows and other information of relevance to the life cycle (construction work, tools, packaging, transport).

List of participants and group members

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Henrik Sandström	Swedish Environmental Protection Agency (Naturvårdsverket)
Hans von Stedingk	Swedish Transport Administration (Trafikverket)
Annika Hanberg	SweNanoSafe

Marie Beckman, SweNanoSafe, also took part in the workshop.

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