Scaffold's results: a summary

Innovative strategies, methods and tools for occupational risks management of manufactured nanomaterials (MNMs) in the construction industry

The FP7 project Scaffold came to an end on 30.04.2015. We present here a summary of its results. More details are provided in Scaffold's final newsletter and in ***20 Scaffold's Public Documents*** *(www.scaffold.eu-vri.eu).*

Context and objectives

The construction industry is the biggest industrial employer in the EU, with 13,9 million jobs, representing 6,4 % of total employment and 29 % of industrial employment. The use of MNMs and nano-enabled products (NEP) in construction is an increasing reality, mostly in cement or concrete products, coatings or insulation materials and to a lesser extent in road-pavement products, building glass, flame retardant or textiles. Most workers and employers in the construction sector (~75%) are not aware of working with MNMs and NEP. Detailed information about product composition and possible nano-specific health and safety issues is generally lacking: the information available for the raw MNM is often lost while stepping down the user chain. As a consequence, it is very difficult for average construction companies to conduct a proper risk assessment and organize a safe workplace for its employees.

The SCAFFOLD research aimed at providing practical, robust, easy-to-use and cost effective solutions for the European construction industry, regarding occupational exposure to MNMs.

Prevention – safety by design

Scaffold has developed innovative strategies for Risk Prevention in selected scenarios and products of the construction sector, as reported in Table 1 below.

Table 1: MNMs applications and risk prevention strategies proposed by Scaffold

MNMs	Application	Strategy
TiO_2	Self-cleaning and depolluting mortar	Use concentrated and stable dispersions Use n-TiO_2supported on sepiolite microfibers (Figure 1)
SiO_2	Self-compacting concrete	Use concentrated and stable dispersions
Nanoclay	Fire resistant polymeric panels	The thermal treatment led to a reduction of the smoke and slight reduction in heat release from the panels in case of fire Low energy mixing processes were found to result in equivalent fire performance to high energy mixing processes. Therefore low energy processes could be selected in order to reduce the particle release
Cell NFs	Insulating polyurethane foam	Achieve good dispersions-MNM bounded to the matrix (to reduce the likelihood to release free MNMs from solid matrix)
CNFs	Composite materials for electromagnetic interference shielding	

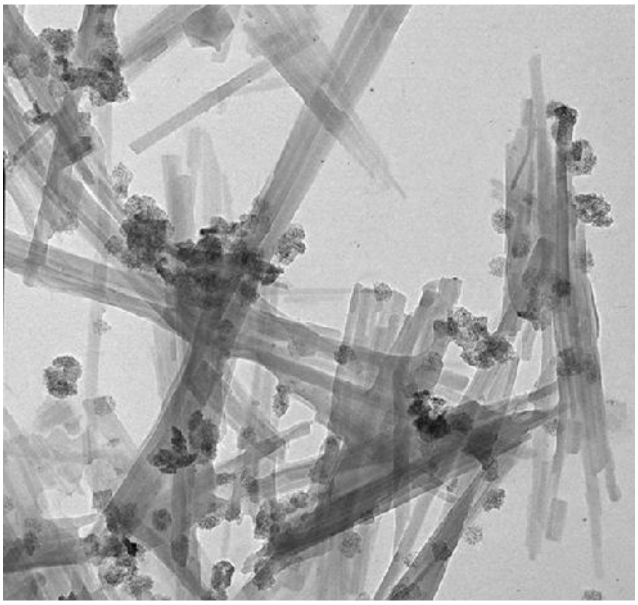

Figure 1: Spherical TiO_2 nanoparticles supported on sepiolite microfibers. Scale is 100 nm.

Release and exposure, assessment

The Scaffold project measured particle release and occupational exposure (inhalation, dermal) at pilot scale, lab scale and in real scenarios, considering: 5 MNMs (TiO_2, SiO_2, carbon nanofibres - CNF, cellulose nanofibres – CeNF, and nanoclays), 6 applications (depollutant mortars, self-cleaning coatings, self-compacting concretes, fire-retardant panels, coating laminates and insulations) and 5 scenarios (manufacture of NMs, manufacture of products containing MNMs and application, machining (drilling, sawing), demolition and fires).

Workers were not overexposed to MNMs in the processes monitored and the measured exposure was below limits (**OELs) selected or proposed by Scaffold** for the five MNMs (Table 2 below). The highest mass concentration of MNM was measured in tasks where nano-powders were handled directly and in significant quantities e.g. cleaning of the reactor and of filters in the nano-TiO_2 manufacturing process, or spraying dispersions of self-cleaning coatings. The highest total particle concentrations were measured while machining hard materials like self-compacting concrete and laminates filled with CNF, with no clear difference between conventional and nano-enabled materials and with no observation of free nano-object. Dust peaks were also observed during e.g. manual adding of powder additives or demolition tasks, with average 8-hour exposure still below the limit value, and a large and complex variety of particles of all sizes, mainly bound in the matrix. In construction, exposure to mixed types of dust and to chemical compounds (including carcinogenic asbestos, crystalline silica, and solvents), is common and may often be of higher relevance than the exposure to MNMs, which are typically included in the products at concentrations below 1,5 %.

Table 2: OELs proposed by Scaffold

Nano-object	OEL (mg/m3) or fibers/cm3 (1)	Reference Values particles/cm3 or fibers/cm3(1)
nano-TiO2	0.1	40.000
nano-SiO2	0.3	40.000
nano-clay	0.3 (respirable) & 4 (inhalable)	40.000
Low toxicity dust	0.3 (respirable) & 4 (inhalable)	
nano-cellulose	0.01 (1)	0.01 (1)
Carbon nano-fiber	0.01 (1)	0.01 (1)

Fire tests performed with conventional and nano-enabled materials showed differences in fire behaviour in the presence of the nano-objects. However, none of the nano-objects introduced in the materials was identified in the combustion effluents, with the possible exception of nano-clays from the fire retardant panels.

Protection equipment

Experimental investigations of collective protection were carried out in nine rooms with different ventilation systems. Particles from the processes were prevented from reaching the room air only when works were conducted in the glove box or with positive pressure room ventilation.

The efficiency of different types of current respiratory protective devices intended for use in construction industry and of three types of clothes generally used by workers on construction sites were tested with different nanoaerosols in to enable a proper selection for different workplaces and hazards. The Total Inward Leakage (TIL) of nanoparticles was measured with a breathing manikin simulating natural human movements and speech. The highest TIL was found for simulation of speech and of up and down head movement. The highest effectiveness of protection was recorded for the full-face mask used with P3 filters and the TH2 powered filtering device incorporating a hood.

Table 3: Examples of protective devices investigated

Enclosure/containment systems used by Scaffold partners, from natural ventilation to the glove box. Pictures: • Natural Ventilation (left) • Closed reactor with regular opening (right)	 
Most commonly used respiratory protective devices: • FFP2 and FFP3 filtering half masks (left picture) • Half masks • FFA1P2 and FFA2P3 filtering half masks against (among others) particles • Full face masks • Powered filtering device with hood (right picture)	 
Gloves (A, B, C, D) Pictures: B (left) and D (right)	 
Clothes: • Fleece jacket 100% polyester (left picture) • Jacket composed of 65% polyester and 35% of cotton (picture in the middle) • Rain jacket composed of polyamide coated with polyurethane • Chemical protective clothing category 3, type 5 and 6 (right picture)	  

The observation of PPEs involved in real scenarios at industrial partners' workplace showed that the current gloves, masks and Tyvek clothes are efficient towards NPs incorporated in a material at realistic concentrations (between 0,4 and 1,7%). Whether in powder form (synthesis of NPs, manufacturing of the mortar) or in solid state (mortar with water, applying on a wall) or in sol-gel state (liquid mortar), we never observed SiO_2, TiO_2, nanoclay or nanocellulose inside PPEs. Regarding the nature of the clothes, the rain coating was the most efficient material, with no diffusion observed at all (aerosol and liquid). The polyester 65%/cotton 35% material was efficient only for SiO2 aerosol and the fleece jacket for SiO_2 aerosol and TiO_2 aerosol.

Case studies

One of the integral parts of project was to test Scaffold's risk management model in real work with manufactured nanomaterials (MNMs) in five Industrial Use Cases (IUC) in real companies for different steps of the life cycle of construction products. After the implementation, an external audit was carried out in each of the company. This allowed to check and improve the versatility of solutions proposed by the Scaffold project. In addition during the audits a monitoring of the presence of nanoparticles was made through the above selected processes for case studies. It allowed to check if the assumptions of exposition for MNMs obtained during the pilot works in the previous work packages were appropriate for the real work with MNMs. The results of the audits is used not only for companies in the successful implementation of the new system, but also served in the further improvement of the developed risk management system.

Figure 2: Workers in Romania and Poland performing various works involving materials with MNMs, with simultaneous measurement of the NP concentrations in air.

Library of Solutions, management

As a main outcome, the project SCAFFOLD has released a Library of Solutions including:

- 4 **quick guides** (risk prevention, risk assessment, risk protection and risk management) **for OSH managers** in construction,
- a **Toolkit** (software) to facilitate the diagnosis, implementation and audit of nanorisk management in large and small construction companies.
- **a handbook for risk management** (new deliverable in preparation).

Besides, Scaffold developed a **customized Control Banding approach** for the construction sector, implemented in a fully functional XML-based macro-enabled **Microsoft Excel workbook**.

Standardization

CEN/TC 352 "Nanotechnologies" (WG3/PG5) is preparing a Technical Specification (TS) based on Scaffold's results: "Manufactured nanomaterials (MNMs) in the construction industry. Guidelines for occupational risk management".

European strategy

Considering the state of the art and of the praxis and the regulatory and research context at the end of the project, Scaffold proposes a European strategy to further improve the management of occupational risks related to MNMs in construction.

Disclaimer – stakeholder consultation in Scaffold

Scaffold's guides, toolkit, roadmap & strategy were prepared following extensive consultation with a range of stakeholders (via workshops, meetings, surveys, interviews and document reviews):

- Representatives of the construction sector, including:
  - European Construction Industry Federation (FIEC);
  - European Federation of Building and Wood Workers (EFBWW);
  - OHS Managers from several construction companies.
- Manufacturers of construction products;
- European and Spanish agencies for occupational safety;
- Manufacturers of personal protection equipment;
- Experts in nanosafety;
- Policy makers at European and national (Spain) levels.

The Scaffold research has received funding from the European Community's Seventh Framework Programme (FP7/20072013) under grant agreement number 280535.