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PROJECT FINAL REPORT

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

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1. FINAL PUBLISHABLE SUMMARY REPORT

1.1 EXECUTIVE SUMMARY

The aim of project SCAFFOLD is to develop, test, validate in real conditions and disseminate a new holistic, consistent and cost effective Risk Management Model (RMM), constructed by integration of a set of innovative strategies, methods and tools developed by the project into consistent state-of-the-art OHS management systems (OHSAS 18001 + ISO 31000).

Whit the aim of achieving this concept, in a first step SCAFFOLD will collect, review and analyse relevant information on state-of-the art strategies, methods and tools for the management of occupational nano-risks in construction, in order to identify needs and gaps. Secondly the project will develop a focused research in the fields of risk prevention (safer materials), risk assessment (inhalation and dermal), risk protection (collective and PPEs) and risk management (models and tools), to cover identified gaps and provide innovative solutions (products, strategies, methods and tools). All these results will be integrated to construct an innovative Risk Management Model (RMM) – using OHSAS 18001 and ISO 31000 standards as skeleton – and develop an advanced software to facilitate its implementation (RMM-Toolkit).

In order to ensure the robustness, soundness and cost-effectiveness of the RMM and Toolkit, five testing and validation activities in real industrial scenarios (Industrial Use Cases) will be carried out in a sample of European companies of the construction sector (large companies and SMEs), including the following activities: 1) Manufacturing nanomaterials (SiO_2), 2) Manufacturing nano-enabled products (fire resistant panels), 3) Use of nano-enable products in building construction (application of n-coatings with different methods), 4) Use of nano-enabled products in civil construction (concrete slab) and 5) End of life of nano-enabled products (Demolition of fire resistant panels with different tools).

The research conducted by SCAFFOLD will consider: 1) Five types of nanomaterials (TiO_2, SiO_2, carbon nanofibres, cellulose nanofibers and nanoclays), six construction applications (depollutant mortars, self-compacting concretes, coatings, self-cleaning coatings, fire resistant panels and insulation materials) and twenty-six exposure scenarios, including lab, pilot and industrial scales.

The main expected results will be: 1) safer nano-enabled products for the construction industry and other industrial sectors, 2) new technologies for manufacturers of nanoparticle measurement equipment, 3) new methods for testing nano-enabled products and PPEs and 4) new strategies, methods and tools to supply advanced services in the field of testing, consulting, training and certification to the construction industry in particular and the European industry in general. The main impacts are expected in construction as well as other sectors such as nanotechnology, manufacturing equipment for collective protection and PPEs, and OHS services for industry. The impact on standardization will be also relevant.

1.2 SUMMARY DESCRIPTION OF PROJECT CONTEXT AND OBJECTIVES

The European construction industry (2013) contributes 8,8 % to the EU-28 GDP and employs 13,9 million people - 6,4 % of total employment and 29 % of industrial employment - in 2,9 million enterprises, most of which – 95 % - are SMEs with less than 20 operatives.

The use of manufactured nanomaterials (MNM) and nano-enabled products (NEP) in construction and the related infrastructure industries is an increasing reality, mostly in cement or concrete products, coatings or insulation materials and to a lesser extent in road-pavement products, flame retardant materials or textiles.

Occupational exposure to these emerging risks may be accidentally or incidentally produced at different stages of the construction industry life cycle. A majority of workers and their employers in the construction sector (~75%) are not aware that they actually work with MNMs and NEP. Detailed information about the product composition and their possible nano-specific health and safety issues is generally lacking and the information available for the raw material manufacturer 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.

In this context, the project SCAFFOLD is a three years industrial oriented idea (2012-2015), funded by the European Commission under FP7, specifically addressed to provide practical, robust, easy-to-use and cost effective solutions for the European construction industry, regarding current uncertainties about the occupational exposure to MNMs and NEPs.

The aim of the project is to develop, test, validate in real conditions and disseminate a new holistic, consistent and cost effective Risk Management Model (RMM), constructed by integration of a set of innovative strategies, methods and tools developed by the project into consistent state-of-the-art OHS management systems (OHSAS 18001 and ISO 31000).

The project SCAFFOLD has the following specific S&T objectives:

1. To profile the European construction sector, identifying needs and gaps in the field of occupational exposure to MNMs
2. To develop novel methods leading to the formation of less risk-posing MNMs: safer concentrated dispersions of metal oxide nanoparticles.
3. To propose safer process alternatives for nanocomposite / coatings production jointly with safer nanocomposites and coatings formulations (minimising emissions in machining / spraying tasks or in case of fire).
4. To develop strategies for safe nano-filled construction products
5. To produce novel strategies and methods for occupational risk assessment (inhalation and dermal) by measurement and modelling
6. To formulate proposals for OELs
7. To adapt and validate the Control Banding approach for construction
8. To develop strategies and methods for exposure assessment in accidental situations
9. To test the efficiency of current alternatives for collective and personal protection (respiratory and dermal) and develop novel strategies for risk protection
10. To develop procedures for monitoring the health of workers
11. To adapt and validate the Control Banding approach to the construction
12. To develop new devices for trapping nanoparticles

13. To construct a robust and cost-effective Risk Management Model (RMM), fully customizable for SMEs, to manage the occupational exposure to MNMs along the life cycle in construction. It will include an innovative software tool (RMM-Toolkit) to support the implementation.
14. To test and validate the RMM & Toolkit in real industrial scenarios, in a set of five industrial use cases.
15. To deploy a strategy to promote implementation of the SCAFFOLD approach in the European construction industry, including the production of guidelines and strategic documents.
16. To coordinate actions with the European NSC and partner form the USA to maximize the project's impact.
17. To impulse the production of new standards (EN)

With the aim to achieve all these objectives, as a first step, SCAFFOLD will collect, review and analyse relevant information about strategies, methods and tools for the management of occupational exposure to nanomaterials in construction, in order to identify needs and gaps. Secondly the project will develop a focused research in the fields of risk prevention (safer materials), risk assessment, risk protection and risk management, to cover identified gaps and provide innovative solutions (new strategies, methods an tools). All these results will be integrated to construct an innovative Risk Management Model (RMM) – using OHSAS 18001 and ISO 31000 standards as skeleton – and develop an advanced software to facilitate its implementation (RMM-Toolkit). In order to ensure the robustness, soundness and cost-effectiveness of the RMM & Toolkit, five testing and validation activities (Industrial Use Cases, IUCs) will be carried out in real conditions, in a sample of European companies of the construction sector (large companies and SMEs) (Table 1).

The research conducted by SCAFFOLD will consider:

- Five types of nanomaterials (TiO_2, SiO_2, carbon nanofibres, cellulose nanofibers and nanoclays),
- Six construction applications (Depollutant mortars, self-compacting concretes, coatings, self-cleaning coatings, fire resistant panels and insulation materials) and
- Twenty-six exposure scenarios, including lab, pilot and industrial scales, an finally

IUC	Company	Country	Size	Exposure scenario
1	TECNAN	Spain	SME	Manufacturing nanomaterials : nano SiO_2, powder
2	ICECON	Romania	Large	Manufacturing nano-enabled products: Fire resistant panels
3	MOSTOSTAL	Poland	Large	Use of nano-enable products in building construction: Application of coatings (different methods)
4	ACCIONA	Spain	Large	Use of products containing nanomaterials in civil construction: Construction of a concrete slab
5	ROSSAL	Romania	SME	End of life of nano-enabled products: Demolition of fire resistant panels (different tools)

Table 1.- Industrial Use Cases (IUCs)

1.3 DESCRIPTION OF THE MAIN RESULTS/FOREGROUNDS

WP1: Profiling the European construction industry

Task 1.1 Developing a Life Cycle Analysis (LCA) for project selected MNMs

In this task an LCA for each of the selected MNMs in different steps of the construction processes has been elaborated. Firstly, the different activities of the construction sector have been classified according to their nature. Traditional definitions of these processes have been included. The five nanomaterials studied in the SCAFFOLD project, as well as their main applications have been defined. Each of the considered constructive processes has been divided in steps in which the MNMs could be potentially present (Figure 1.1). For each of the steps of the defined constructive processes, the occupational exposure scenarios for each of the selected MNMs have been identified.

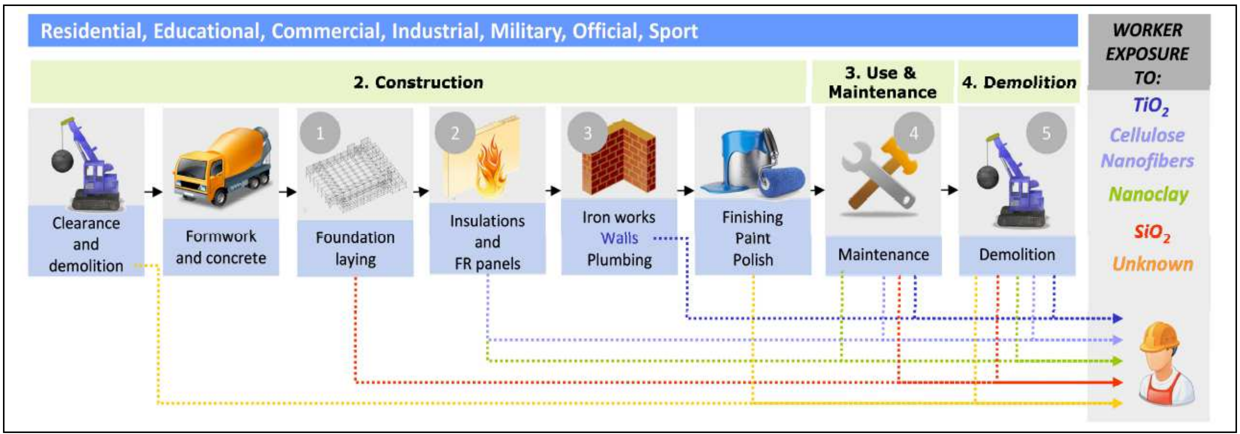

Figure 1.1. Steps of the building process identifying the potential presence of each MNM

Task 1.2-Analysing and collecting sound available information, on occupational exposure to MNMs.

The objective of Task 1.2 was to collect and analyse the available data on exposure to manufactured nanomaterials (MNMs), the potential toxicity of those materials, and risk management measures. The data was collected by systematic literature searches. The focus was on finding data specifically related to the use of MNMs in the construction field.

However, very limited data has been found, and thus also more general data was included. In the health hazard assessment part, toxicological information was assembled only on the nanomaterials selected for the SCAFFOLD project. In addition to the literature review, a questionnaire was distributed to the SCAFFOLD industry partners, as well as to the European Construction Industry Federation (FIEC) in order to get an overview of the current status of awareness, exposure and risk management with respect to nanomaterials at workplaces within the construction sector.

Task 1.3-Profiling needs and gaps on occupational exposure to MNMs in the construction industry.

The work carried out within task 1.3 was concentrated in the development of a roadmap for the construction sector. The document contains and updated vision of the construction sector and of its occupational safety issues related to nanomaterials, and further develops a roadmap on occupational exposure to MNMs in the construction sector. The roadmap has been designed to support the identification of future product, service and technology needs for the occupational risk management of MNMs in the construction sector, and the evaluation and selection of the technology alternatives to meet these needs. The roadmap –in its former intermediary versions-has been used as a guide all along the Scaffold project.

This document has been prepared following extensive consultation with a range of stakeholders (via workshops, meetings, surveys, interviews and document reviews): representatives of the construction sector (European Construction Industry Federation (FIEC), European Federation of Building and Wood Workers (EFBWW) and OHS Managers from several construction companies), manufacturers of construction products; European and Spanish agencies for occupational health and safety; manufacturers of personal protection equipment; experts in nanosafety; policy makers at European and national (Spain) levels.

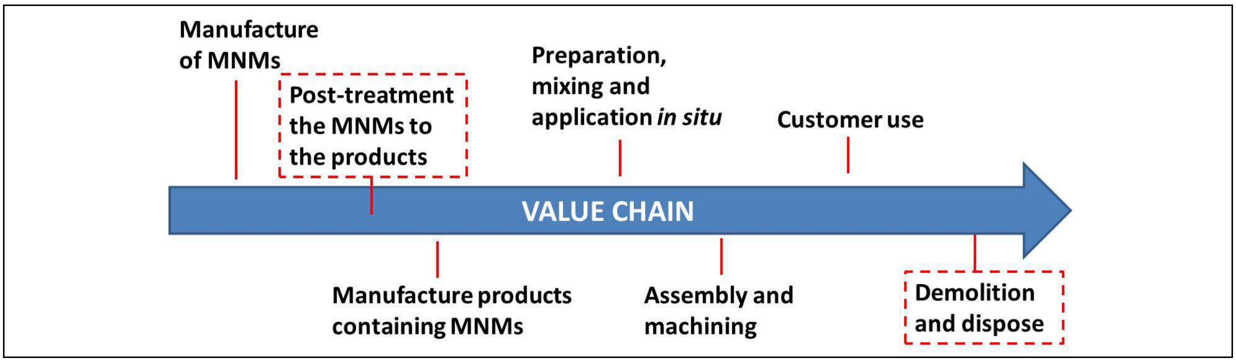

Figure 1.2 Value chain of the MNMs in the SCAFFOLD project

Actions	Type of action	Challenges
Short term	-Personal protection -Safe Work Practices -Spill Control during professional and/or consumer use	-Implementation of safer work practices including PPE -Implementation of Best Practice Guides -Implementation of RMM and Toolkit in Risk Management systems of enterprises
Medium term	-Need for better accessible information -Safety, risk assessment, and risk/benefit assessment -Technical measures	-Transparency of information regarding MNMs, promote education and training -Carry out specific risk assessments (contact MNMs supplier when data is not provided in MSDS) -Application of substitution and prevention-by-design principles -Evaluation of exposure and implementation of control banding tools and OELs -Enclosure of processes
Long term	-Health, safety and environment protection in EU legislation	-A final assessment on a review of occupational health and safety legislation, including areas of legislation such as air, water, waste, industrial emissions and worker protection legislation

Table 1.1 Summary of the roadmap

Work Package 2: Risk Prevention

Task 2.1 – Developing intrinsically safe MNMs formulations

Flame spray pyrolysis was used to produce high-purity, spherical TiO_2 and SiO_2 nanoparticles. Highly concentrated aqueous dispersions of these nanoparticles were then developed, which will allow safe transportation and handling in subsequent processing operations.

Two different grades of bespoke organomodifed clay were also produced, by modifying a commercially available organomodified bentonite. These materials would ultimately be used in the development and production of fire retardant unsaturated polyester composites, therefore the aim of the bespoke modification was to reduce smoke emission, whilst maintaining good compatibility with the polymer.

Task 2.2 – Developing fire retardant nanocomposite panels with minimum risk to health & safety

A range of mixing and dispersion techniques and parameters were investigated, in order to determine the effect of clay incorporation method on the mechanical and fire properties on unsaturated polyester resin composites. It was found that the use of lower energy processes had no discernible effect on the ultimate fire or mechanical performance. One advantage of this result, from the point of view of worker health and safety, is that the lower energy processes are less likely to raise dust and/or aerosols containing nanoparticles.

Task 2.3 - Developing strategies for safe nano-filled concrete, bituminous pavements, coatings and insulation

The novel TiO_2 and SiO_2 materials developed in Task 2.1 were utilised to develop new formulations for depollutant mortar and self-compacting compact, respectively. Alongside this, novel formulations for polyurethane insulation panels (containing cellulose nanofibres) and electromagnetic interference shielding composites (containing carbon nanofibres) were also developed. Each of these new formulations was tested and evaluated against traditional analogues.

Task 2.4 – Integrating a common vision: new strategies, methods and tools for MNMs Risk Prevention

An explanation of the safer-by-design strategy developed within the project was included in a Best Practice Guide; drawing on results from the technical evaluations carried out in Tasks 2.1, 2.2 and 2.3, and from feedback gained from a variety of industrial stakeholders.

Work Package 3: Risk Assessment

Task 3.1 Hazard assessment

The toxicological information on each of the nanomaterials included in the project (amorphous silica (SiO_2), titanium dioxide (TiO_2), carbon nanofibres, nanoclays and nanocellulose) was collected. The detailed information for each of the substances was documented in tables.

Task 3.2. Developing strategies and methods for exposure assessment by measurement

Data on occupational exposure (inhalation & dermal) were achieved in the scenarios in the scope of the project. In the figure 1 it is showed a matrix with the scenarios considered and a picture taken during the measurements in a specific construction process. In brief, the results showed that workers were not overexposed to NOAAs in the processes monitored and values of occupational exposure were below limits selected by SCAFFOLD.

Measurement results were collected in a excel Database. From the experience gained on the measurements, we proposed methods for exposure measurement containing decision making matrices and flow charts to guide the assessment process.

	Nano-object and application					
Life cycle step	nano-TiO2 depollutant mortar	nano-TiO2 self-cleaning coating	nano-SiO2 self-compacting concrete	nano-Clay(fire retardant panels	carbon nano-fibers coating laminates	nano-cellulose insulations
Nano-object manufacturing	x	x	O			
Manufacturing nano-enabled products and application	x	x	O	O	x	x
Use/maintenance: Machining	x	x	x	(x)	x	x
Demolition	x	x	x	(x)	x	x
Accidental fires	x	x	x	x	x	x

X scenarios measured at lab/pilot
O scenarios measured in Industrial Case studies

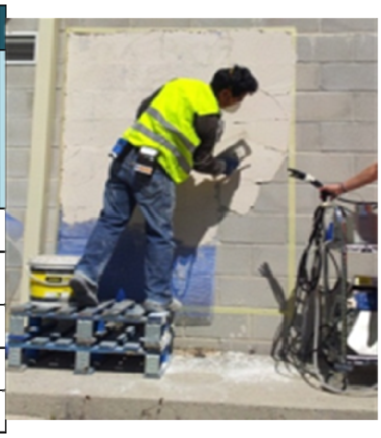

Figure 3.1 Matrix summarizing the scenarios monitored in SCAFFOLD (left); picture taken during the measurements in a construction site (right).

Task 3.3 Developing strategies and methods for exposure assessment by modelling (Inhalation & Dermal)

Workers exposure was assessed by modelling in a real production site of n-TiO_2 during hypothetical accidental releases (see figure 3.2). In this activity, seven specific accidental scenarios were developed, computational grids created, followed by the simulation of the NOAAs dispersion in the site. Final results showed the exposure concentration of the TiO_2 at the Personal Breathing Zone (PBZ) of workers in different areas of the production site. From these data, the doses in the different regions of the Human Respiratory Tract (HRT) were estimated through computational modelling. Overall, an integrated, multiparametric methodology was created that can be used for estimation of internal doses by inhalation due to specific particles release scenarios. The last task related to modelling addressed of dermal exposure using models available in literature. First, the applicability for MNMs of different models of dermal exposure was analysed. DREAM model was considered more relevant for the project and it was applied to eight scenarios in the scope of the project for comparison with real data achieved in the measurement campaign. This activity showed that this tool can be a powerful tool to help to prioritize activities based on potential dermal exposures.

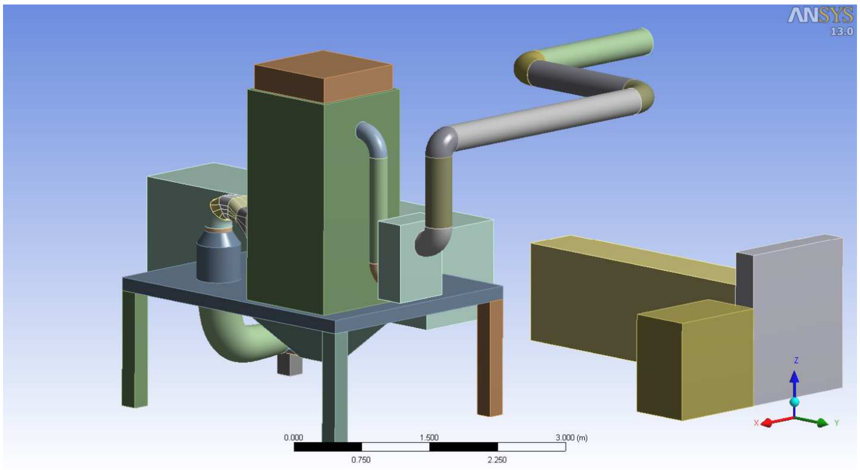

Figure 3.2 Parts of the production machine used for the simulated accidental scenario.

Task 3.4 Testing new devices for exposure measurement

This task developed an intercomparison study with a set of on-line aerosol analysers, used to evaluate the occupational exposure to nanoSiO2 (PNC), in a real industrial scenario of manufacture of nanoSiO2 by FSP (Flame Pyrolisis Spray). The intercompared analyzers were: 1) a NanoScan (TSI 3910) and OPS (TSI 3330), against 2) three other analyzers of the state of the art (Dekati ELPI+, TSI Areotrak and CPC TSI 3007). The use of instrumentation with different physical measurement principles (mobility diameter, aerodynamic diameter) and measuring ranges as well as the very dynamic characteristics of multisource industrial scenario (MSIS), induced significant bias in the results. Therefore, new intercomparison studies are needed to validate the use of this type of instrumentation in real MSIS.

Task 3.5: Developing strategies and methods for exposure assessment in accidental situations: fire

Risks associated to accidental situations in case of fire were studied. Samples of materials developed in the project were tested in order to evaluate the influence of the nano fillers in the reaction to fire properties.

Methods qualitative and quantitative were developed to identify and analyze the potential release of NOAAs in the effluents resulted from the combustion. The experimental data showed the effects of the incorporation of the n-fillers in the fire propagation, smoke density and smoke toxicity. Data suggested that none of the materials released NOAAs during the combustion, with the exception of the fire retardant panels filled with nano-clays where it was found some indications of potential releases of this material.

Ref.	FIRE PROPAGATION		SMOKE DENSITY		PARTICLES IN EFFLUENTS[*]		SMOKE TOXICITY	
	MARHE		Ds		Nano-objects		CIT_g (8min)	
CONC-A	-		67.42		-		0.009	
CONC-C	-		243.96	↑	n.d.		0.063	
MORTAR-A	-		77.92		-		0.014	
MORTAR-C	-		31.37	↓	n.d.		0.012	
FRPANEL-Control	191.68		1094.16		-		0.338	
FRPANEL-1.25%Dellite	154.85	↓	1320		Evidences[1]		0.887	↑
FOAM-Control	164.15		210.81		-		0.131	
FOAM-0.5%NCC	124.24	↓	188.15	↓	n.d.		0.134	
COM-Control	286.16		1320		-		0.750	
COM-0.5%CNF	296.27		1320		n.d.		0.637	

Table 1.2 Results of the different fire reaction properties for the materials developed in the project.

Task 3.6 Formulating exposure limit values (LVs) (inhalation & dermal)

Occupational Exposure Limit values (OELs) were derived from the analysis of collected data for the NOAAs in the scope of the SCAFFOLD project. In addition, SCAFFOLD also recommended to use the Nano Reference Values (NRF) proposed by IFA(2014) and SER (2012) (Table 3.2).

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)

Table 3.2 OELs proposed by SCAFFOLD for the NOAAs in the scope of the project.

Task 3.7 integrating a common vision: New strategies, methods and tools for MNMs risk assessment.

Main results from the WP3 were collected in a “Best Practice Guide for Risk Assessment”. This guide provides recommendations for the sector to perform the Risk Assessment derived from the use of MNMs in the work place. The Delphi work-shop organized during Nanosafe2014 conference was very valuable to get inputs and recommendations from expertise to this guide.

Work Package 4: Risk Protection

Task 4.1 - Testing efficiency of current alternatives for collective protection

The aim of this task was to test efficiency of the collective protection (existing among partners: ACCIONA, TECNALIA, TECNAN, NETCOMPOSITES, ICECON and CIOP-PIB) during experimental campaigns. The main results obtained during these experiments are listed just below:

- When risks cannot be eliminated at the source, the engineering control has to be considered before any personal protection.
- From the tested air filters, F7+H14 multistage filters or H14 are the most efficient (98% of efficiency).
- Efficiency of fine air filters as classes F7 strongly depended on size of particles. F7 filters are more efficient (90%) for particles having size less than 30 nm and less efficient for bigger sizes, reaching about 60-70%.
- Room with positive pressure ventilation is recommended when work is conducted in a glove box in order to not transfer particles in the room air.
- Fume cupboards should be used according to manufacturer procedure, to ensure designed profile air velocity inside the fume cupboard what allowing decreasing transferring the particles to the room air.
- Processes conducted with local /enclosed mechanical ventilation have to be supported by general mechanical ventilation.
- All items placed in the fume cupboard may change of design profile of air velocity inside the fume cupboard and as effect increase of transferring particles to the room air.
- Work with designed air flow rates of available in the room mechanical ventilation systems is possible only when uncontrolled natural ventilation in not used (opening door or windows).

Task 4.2- Testing efficiency of current alternatives for personal respiratory protection

The aim of this task was to investigate the protection efficiency of different types of current respiratory protective devices intended for use in any construction industry in order to classify them and to enable a proper selection for different workplaces and hazards.

Main conclusions on penetration tests: Particles falling in the size range of 30-60 nm may be deemed to be the most penetrating. The experiments show that P3 filters exhibit the highest filtering effectiveness against all the tested types of nanoaerosols. However, it should be remembered that P3 filters alone cannot provide protection from air pollutants, as they need to be used with face pieces (half masks or full-face masks). Therefore, protective assemblies that are inadequately fitted to the dimensions of an individual user’s face may lead to a decreased level of protection provided or even compromise protection entirely, even if the filter itself meets the relevant protective requirements.

Main conclusions on TIL tests: The highest TIL levels were found for speech simulation and simulation of up and down head movement. The results presented in the report, and especially those pertaining to equipment of the highest protection classes, show that nano-aerosols pose considerable risks and that special safety precautions should be taken in workplaces where nanoparticles are generated as a result of industrial processes. A comparison of TIL results for NaCl obtained from the tests conducted on the manikin with the results obtained from the tests involving human subjects revealed that in both cases the highest effectiveness was recorded for the full-face mask used with P3 filters and the powered filtering device incorporating a TH2 hood. In both cases the lowest effectiveness (below the nominal limits) was obtained for the filtering half masks class FFP2 and FFP3. Therefore it is not recommend to use the filtering half masks in case of occurrence of the nano-aerosols hazards.

Task 4.3 - Testing efficiency of current alternatives for personal dermal protection (clothing, gloves)

Personal dermal Protection Equipment's (PPE) efficiency was characterized toward the nano exposition via nanopowder, nanoaerosol and nanohydrosol. Gloves, masks and tyveks used in real scenarios in the construction sector were sent by industrial partners, the aim of this study was to detect if nanopowders diffuse through these PPEs. Results are gathered in Table 1 and show that all the PPEs involved in real scenarios (gloves, masks, tyveks) are efficient in standard conditions.

Stages PPEs	Producing TiO_2	Manufacturing mortar (TiO_2, SiO_2, Mg)	Applying in a solid state (TiO_2, SiO_2, Mg)	Applying in a liquid state (spray) (TiO_2, SiO_2, Mg)	Demolishing a building (TiO_2, SiO_2)
Gloves	Efficient	Efficient	Efficient	Efficient	NA
Masks	NA	Efficient	Efficient	Efficient	Efficient
Tyveks	Efficient	NA	NA.	Efficient	NA

Table 3.3 Summary of results obtained on PPEs (gloves, masks, Tyvek) used in five real scenarios (NA = not analysed).

The efficiency of selected clothes used in the construction sector towards NPs diffusion was evaluate, whether aerosol diffusion and liquid diffusion, results are gathered in Table 2. PU coated PA was the most efficient cloth towards aerosolized and hydrosol NPs. All the clothes were efficient toward aerosolized nanoSiO_2. The fleece jacket, that was thicker, hold nanoTiO_2 and not nanocellulose and nanoclay. The material composed of polyester 65% / cotton 35% seems to be the less efficient cloth.

Cloth	SiO_2 aerosol	SiO_2 hydrosol	TiO_2 aerosol	Nanocellulose aerosol	Nanoclay aerosol
100% polyester (fleece jacket)	Efficient	Not efficient	Efficient	Not efficient	Not efficient
Polyester 65%/ cotton 35%	Efficient	Not efficient	Not efficient	Not efficient	Not efficient
PU coated PA rain cloth	Efficient	Efficient	Efficient	Efficient	Efficient

Table 3.4 Summary of results obtained on 3 types of cloth generally used by workers on construction sites.

Task 4.4 New strategies, methods and devices for risk protection

The efficiency of gloves and Tyvek against the penetration of nanoparticles in suspension containing 15nm and 40nm with continuous mechanical stress for a period of 7 hours has been demonstrated, see Table 3. When comparing the Low Limit Detection (LLD) of the marked ^{152}Eu NPs (**6.8 10^{10} particles/mL**) to those of the ICPMS for SiO_2 NPs (**1.67 10^{10}**

particles/mL), we conclude that ICPMS remains a good technique to quantify NPs in hydrosols.

Material	Type of NPs	NPs size (nm)	Type of experiment	Time of test	Analysis	Results
Latex glove	SiO_2 + 152Eu	50	Dynamic	7h	γ counting	no diffusion
Nitrile glove	SiO_2 + 152Eu	50	Dynamic	7h	γ counting	no diffusion
Latex glove	SiO_2 + 152Eu	15	Dynamic	7h	γ counting	no diffusion
Nitrile glove	SiO_2 + 152Eu	15	Dynamic	7h	γ counting	no diffusion
Tyvek	SiO_2 + 152Eu	15	Static	96h	γ counting	no diffusion
Tyvek	SiO_2 + 152Eu	15	Piston 1cm	7h	γ counting	no diffusion

Table 3.5 Summary of experimental conditions and of obtained results.

Investigation of the capture efficiency as a function of the applied voltage, of the action of the photoionizer, of the particles diameter and of the chemical nature of the particles was done. The study revealed that we do not need the corona effect to collect efficiently ultrafine. We observed that even at very low voltage, ESP and ESP+PI were efficient. SiO_2 NPs, TiO_2 NPs, nanoclay, nanocellulose and carbon nanofibers of 25, 50 and 100nm of diameter were investigated. ESP alone was very efficient for the smallest NPs (25nm) negatively and positively charged, whatever the type of NPs. Addition of the PI effect enhanced the capture of the bigger NPs (50 and 100nm) for the negative, positive AND neutral charged NPs. Giving conclusions on the capture efficiency in function of the chemical nature of the NPs was quite difficult. ESP alone seemed to be more efficient for the collect of nanoclays and ESP+PI was more efficient for the capture of TiO_2 NPs.

Task 4.5 Customizing Control Banding approach to the construction sector

SCAFFOLD tested the applicability of the well-established Stoffenmanager Nano Control Banding (CB) tool in some of the studied industrial workplaces. One main advantage of using a Control Banding tool is that the company and the workers have to study the MSDS or get other information about the used product and also consider how they are handling it. However, performing the risk assessment using only the Stoffenmanager Nano tool is not enough at construction sites, where the work environment is rather complicated, several different activities are taking place at the same time, and the amounts of chemicals used are often substantial. Other activities and chemicals (which may be much more hazardous than the nanomaterials) must also be included in the assessment.

SCAFFOLD developed a customized CB approach and implemented it as a fully functional XML-based macro-enabled Microsoft Excel workbook. The tool considers the materials and construction processes treated during the project, but can be applied to other construction scenarios as well. The allocation of hazard bands is according to the ISO/TS 12901-2 (2014) standard. The proposed respiratory exposure algorithm follows the Stoffenmanager approach and incorporates modifying factors related to source emission and dispersion of nanomaterials. The generic exposure is represented as a multiplicative function of type of handling and intrinsic properties of the material. The developed dermal exposure algorithm is according to the DREAM model. Significant effort is made to minimize the required inputs for the respiratory and dermal exposure algorithms, and avoid any overlapping of input data. The tool also supports the selection of protective measures and assesses their impact on respiratory and dermal exposure control. Risk levels are divided into five risk bands according to the BS 8800 (2004) standard.

Task 4.6 - Developing procedures for monitoring health of workers

The aim of the task was to develop an exposure register model and guidance for monitoring health of probably exposed workers.

At first, the exposure register model for construction industry was defined. At the moment, when there are no uniform national or international regulations for collecting nanomaterial exposure data, the construction companies or their occupational health care units are recommended to collect exposure data and include it in a register. A guidance document (leaflet) proposing a procedure for monitoring the health of the nanomaterial exposed workers was therefore developed. The draft guidance document was circulated among occupational physicians and updated on the basis of their feedback. The leaflet is easy to read and understand, but in cases where the occupational health care professionals need more information, they are advised to check the publicly available full deliverable.

The recommendations presented conclude that **in most cases, applying normal medical surveillance practices for construction workers is applicable also in situations involving nanomaterials**. The interval between periodic examinations varies from 1 to 5 years depending on exposures and age of the worker. Construction work involves several types of health risk, which have to be taken into consideration. In case of high risk level (for example nanofibers or other nanomaterials of high concern are used and exposure is high), it is recommended to include regular follow-up examinations, focusing on respiratory and cardiovascular systems.

Task 4.7 Integrating a common vision: New strategies, methods and tools for MNMs risk protection

With all of the results obtained in this work package and based on discussions having during the Delphi workshop, we gave some recommendations for the construction industry in which workers are exposed to nanomaterials, dusts and other substances that may cause adverse health effects. Various recommendations are given because NPs and NMs are manipulated during different steps of their life cycle (synthesis, handling, mixing, applying, demolishing). The main recommendations are summarized just below:

1. Two decision trees have been made, one for the manipulation of NPs and the second for the manipulation for MNMs, allowing us to classify 9 levels of hazards present in the construction sector.
2. We distinguish nanoparticles and nanofibers because of their morphology (length-diameter aspect ratio larger than 3) which is in relation with their toxicity as asbestos fibers
3. The limit values for liquid (1L) and powder (100g) were selected because many products are conditioned with this volume and this weight. For aerosolized particles we use the limit recommended by IFA (40 000 p/cm3) (Institut Für Arbeitsschutz der DGUV)
4. Recommendations are given for ingestion, inhalation and dermal contact.
5. Feature of this sector: work INDOOR and OUTDOOR:
6. If OUTDOOR → no collective protection
7. If INDOOR, collective protection has to be implemented at first.

8. If no collective protection OR collective protection is not sufficient, personal protections equipment have to be implemented
9. The aim of this study was to propose collective and personal protections against NPs which were appropriate to this sector and to each scenario, with minimizing the burden.
10. For the recommendations, we assume that all the NPs are always isolated; even it is not the case in real life because industrials can't observe NPs by SEM or TEM (precautionary principle).

Work Package 5: Risk Management

Task 5.1 Risk Management Model (RMM) development

In T5.1 a novel Risk Management Model (RMM) was developed for managing nano-risks in construction. The model presents itself an innovative conceptual work. It was designed using requirements of OHSAS 18001 (structure, elements, etc.) as skeleton, including additional requirements derived from guidelines established in ISO 31000 and integrating specific elements developed by the project on risk prevention, risk assessment, risk protection and risk management.

The outlined RMM can be applied in any type of organization irrespective of size and type, in all its areas and levels. Every subsector involved in construction cycle could apply this model but with different necessities, perceptions and criteria (manufacture, building and civil construction and demolition). In addition, this design allows the integration of RMM with the other management systems (e.g. ISO 9001, ISO 14001) especially for the common requirements (systems requirements as document control, audits, training, etc).

The RMM includes specific considerations on initial review, monitoring and audit and can be certificated. The implementation of this RMM will allow the organization to consider nano-risks into OHSAS system. On the other hand, if the organization has no experience on a systematic approach for managing its occupational health and safety risks, the implementation of RMM could be the first step for a more complete and organized perspective of OHS risks. An organization that proves the successful implementation of this model should ensure all interested parties that has an appropriate management of nano-risks.

Task 5.2 Developing a Toolkit with innovative tools for RMM initial review, planning, implementation, monitoring and audit

This task developed the SCAFFOLD Toolkit (Toolkit), a basic modular architecture tool that allow companies– Large and SMEs – to support the initial review, implementation, monitoring and audit of RMM. The RMM-Toolkit represents the integration of all the solutions developed by the project in the fields of risk prevention, risk assessment, risk protection and risk management, in a software tool, friendly, easy to use and customizable for SMEs. It consists in a standalone desktop application for the Windows platform.

The Toolkit enables companies with an OSHAS model implemented to consider the management of nano-risks into this model, but also to companies with no experience in health and safety management systems, particularly SMEs, to initiate the path to a complete OHS management with the implementation of RMM as first step.

MNMs Risk Management Model	
0	Introduction
0.1	General
0.2	General principles in MNMs risk management
1	Scope
2	Normative references
3	Terms and definitions
4	Requirements for the occupational health and safety MNMs Risk Managament Model (only title)
4.1	General requirements
4.1.1	Context
4.1.2	Necessities and expectations for stakeholders
4.1.3	Scope determination and requirements for the MNMs RMM
4.2	OHS policy and management commitment
4.2.1	Management commitment
4.2.2	MNMs risk management policy
4.3	Planning (only title)
4.3.1	MNMs hazard identification, risk assessment and control determination
4.3.1.1	General
4.3.1.2	MNMs risk identification
4.3.1.3	MNMs risk evaluation
4.3.1.4	MNMs risk treatment
4.3.2	Legal an other requeriments
4.3.3	Objectives and programmes
4.3.3.1	Objectives, goals and programmes of risk management for
4.3.3.2	MNMs risk management planning
4.4	Implementation and operation (only title)
4.4.1	Resources, roles, responsibility, accountability and authority. General.
4.4.1.1	Responsability and authority
4.4.1.2	Management representative
4.4.1.3	Infraestructure

Figure 5.1 Architecture of RMM

Task 5.2 Developing a Toolkit with innovative tools for RMM initial review, planning, implementation, monitoring and audit

The aim of this task is to develop the SCAFFOLD Toolkit (RMM-Toolkit), a modular software tool to facilitate the implementation of the RMM. The RMM-Toolkit represents the integration of all the solutions developed by the project in the fields of risk prevention, risk assessment, risk protection and risk management, in a software tool, friendly, easy to use and customizable for SMEs. It consists in a standalone desktop application for the Windows platform.

The Toolkit deploys: 1) Five operational modules (Library, Customization, Risk management, Tools and Help), 2) Two setups, a general setup for large or advanced companies on risk management, and a customized setup for SMEs and 3) Two operational modes, learning and risk management. Tables 5.2 and 5.3 display the main characteristics and contents of modules and operating modes.

Module	**Description**
1. Library	It provides a library with documentation to help the companies of the construction sector to deal with the risks arising from MNM.
2. Customization	It allows companies to customize the application to their processes, tasks, scenarios and size. It uses the Module 1 to facilitate data input and generate the company profile.
3. Risk Management	It enables the initial assessment, implementation and audit of RMM guided by a step-by-step dialog. This module deploys two different setups, depending on the company profile (Large company or SME).
4. Tools	It contains the toolbox for nanosafety management.
5. Help	It gives access to miscellaneous options: file management, configuration, and help (User manuals).

Table 5.2 SCAFFOLD Toolkit: Software modules

Operation mode	Description
Learning	The toolkit is used for training (e.g. toolbox), general information and communication (e.g. NOAA, hazards, control measures, good practices, etc). Only modules 1 and 4 are operating.
Risk Management	Customized mode. The toolkit is used for diagnosis, implementation, monitoring, auditing and improving the management of nanorisks in a specific construction company. All modules are operating.

Table 5.3 SCAFFOLD Toolkit: Operation modes

The Toolkit enables companies with an OSHAS model implemented to consider the management of nano-risks into this model, but also to companies with no experience in health and safety management systems, particularly SMEs, to initiate the path to a complete OHS management with the implementation of RMM as first step.

Among other, the RMM-Toolkit includes interactive and customized check-lists for diagnostic, implementation or audit the RMM and tools to 1) train workers, supervisors and the high direction on nano-risk management, 2) guide the qualitative and quantitative risk assessment of the occupational exposure to MNMs, 3) monitor the implementation of the control measures, 4) define and monitor Key Performance Indicators, 5) supply templates with procedures, instructions, registers and OHS manuals that can be customized by end-users to facilitate the implementation of RMM and 6) export data produced by the Toolkit to other conventional formats commonly used by companies (e.g. Word, Excel).

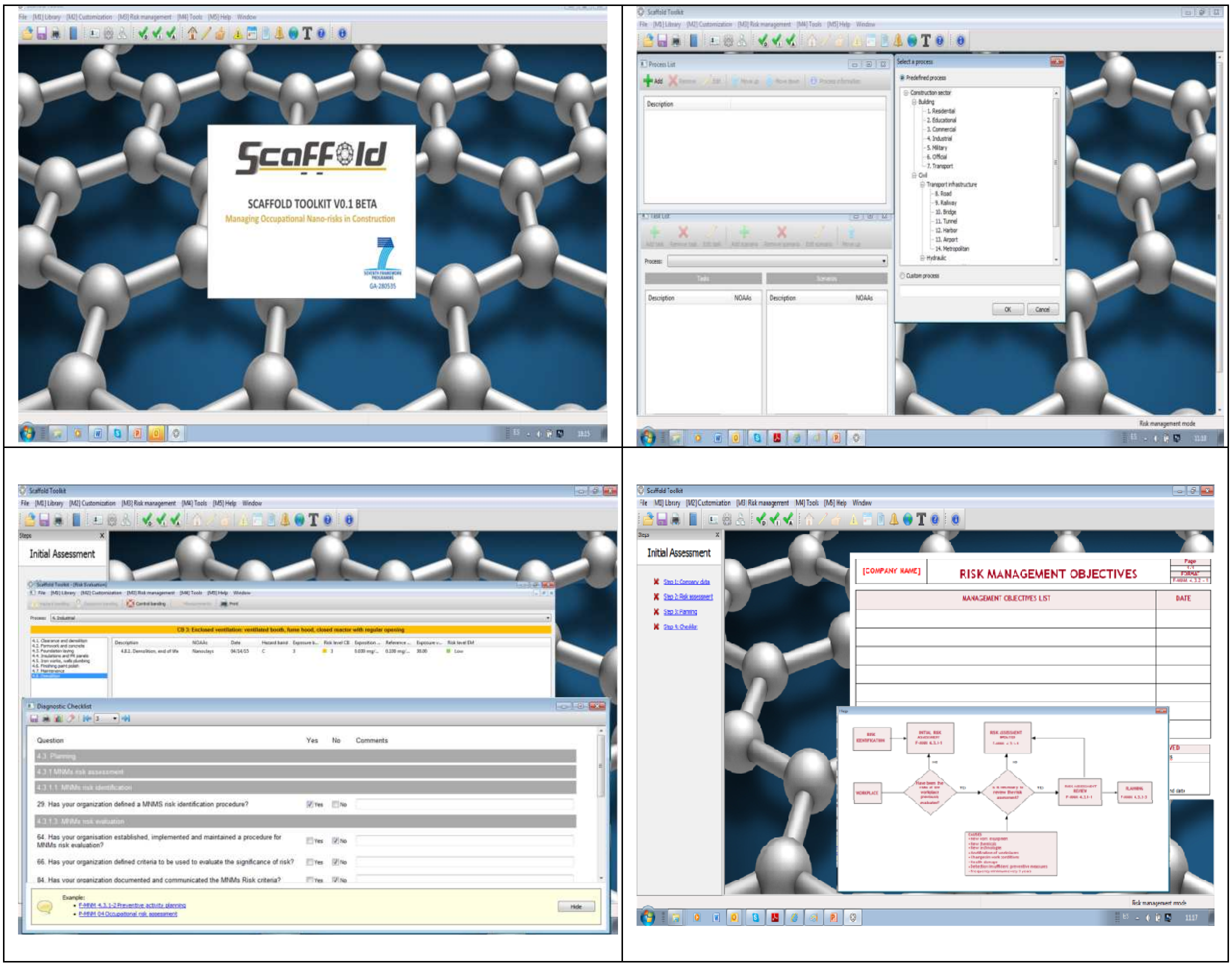

Figure 5.2 The RMM-Toolkit is a standalone desktop application for the Windows platform, friendly, easy to use and customizable for SMEs.

<u>Task 5.3 Customizing the RMM for SMEs</u>

The development of T5.3 ensured fully customization and adaptation of RMM to SMEs. In this respect, several guides and documents containing specifications to establish criteria for interpreting the RMM and facilitate its implementation in SMEs, were elaborated and subsequently implemented in the Toolkit (Customized approach for SMEs).

The customized RMM for SMEs is based on the limited scope of the activities and established criteria for the simplification of documentation, but without a reduction of protection level for the workers. This simplification is principally addressed to reduce the extension of documentation, facilitate its comprehension and provide the templates to be completed by the user to automatically generate some of the RMM documents (manual, management procedures, etc) or formats (policy, management review, non-conformities, etc).

Task 5.4.- Integrating a common vision: New strategies, methods and tools for MNMs risk management

The main results of WP5 were encapsulated in a quick guideline for Risk Management. A Delphi work-shop with the participation of stakeholders of the construction sector (Industrial companies and associations, research organizations, OHS administration, standardization body) was organized to integrate approaches on risk management in a common vision.

Work Package 6: RMM testing and validation in construction industry

Task 6.1 Industrial Use Case 1: Manufacturing NMs for construction products

The objective of T6.1 was to test and validate the RMM & Toolkit in an industrial company manufacturing nano-SiO_2 (TECNAN, Spain). A specific implementation & audit plan was elaborated for the company, including consideration of elements of the CENARIOS model.

The technique used by the company to produce the SiO_2 nanoparticles and carry out the exposure measurements is Flame Spray Pyrolisis (FSP). The equipment used in SCAFFOLD project has a production capacity is in the range of 0,5kg/hour and thus supposing a semi-industrial scale. The surface area of these nanopaticles was around 165m^2/g which correspond a size of 14nm.

Figure 6.1 IUC1 – Cleaning the FSP reactor.

The company used SCAFFOLD Toolkit for initial diagnosis of their management system for identification of missing elements regarding work with nanoparticles. Then - with use of the risk assessment and protection guides created in SCAFFOLD project - a new complete documentation was created and implemented for work related with nanoparticles. An external audit and a quantitative risk assessment were performed during production of nanoSiO_2 to validate the implementation, and to additionally check the exposure of workers. The IUC1 proved that SCAFFOLD can be used in companies manufacturing nanomaterials to increase safety of workers

Implementation of SCAFFOLD results into management system of the company was done in easy and fast way due to the toolkit developed during the project is easy to use. The data generated as a result of measurement and external audit of activity have demonstrated that nano-risks are controlled with correct measures. Additionally, these measurements allow the company effectiveness continual improvement of the RMM. It proved also that SCAFFOLD can be quickly implemented in other companies that are already using a management system certified accordingly to OHSAS 18001.

As benefits for the company:

- The enterprise has increased their knowledge about the risk assessment of nanoparticles production during the IUC1 (SiO_2). This knowledge can be extrapolated to other nanoparticles produced by the company.
- The information obtained during the quantitative risk assessment in our facilities has been used to improve the workers safety, elaborating an internal document where it is specify the safety measures needed to produce safely.
- Moreover, the new information will be used in our technical data sheet in order to guarantee to our customers that we produce the nanomaterials safely. These new guides will be useful for the customers in order to ensure their safety in handling the nanoproducts acquired.

<u>Task 6.2 Industrial Use Case 2: Manufacturing of construction products containing MNMs</u>

The IUC2 was conducted in ICECON (Romania). The case study was performed in order to manage workers exposure to released nanopowders of activated nanoclay, that was used in the manufacturing of fire-resistant panels containing MNMs.

In first step SCAFFOLD Toolkit was used for initial diagnosis of management system used in the company. It helped to find a gaps regarding safety of workers involved in production of construction materials enhanced with nanoparticles (Fire retardant panels doped with nanoclays). With the use of guides and RMM-Toolkit a new procedures have been created and implemented. An external audit was then performed during manufacturing process. Results proved that SCAFFOLD can be implemented into companies that produce construction materials enhanced with nanomaterials. In addition a Quantitative Risk Assessment was conducted to check the exposure level of workers.

Implementation was made based on Scaffold Toolkit that was used for validation of the proper introduction of the Scaffold RMM into the company management system. The Scaffold Toolkit was used during IUC 2 for all stages of Risk Management as well as for generating templates for workplace instruction. During the IUC 2 the RMM checklist from the toolkit was used to conduct internal audit.

Implementation of SCAFFOLD results into management system of the company was done successfully, since the company already integrated the management systems (certified accordingly to ISO 9001, ISO 14001, ISO-18001 and OHSAS certificates) results of Scaffold should be just implemented as an addition to that uses procedures, and instructions are already in use. This action proved that SCAFFOLD can be quickly implemented in any company already using a management system certified accordingly to OHSAS 18001.

IUC	Company	Country	Size	Exposure scenario	MNM
2	ICECON	Romania	Large	Manufacturing NEP: Fire resistant panels	Nanoclay

Figure 6.2 IUC2 – Smoothing and levelling.

As benefits for the company:

- Developing the range of products manufactured by the company, by including new recipes using nano-clays; such a product is fire-resistant panel containing MNMs for cladding flat surfaces of buildings elements
- Implementation in the companyt, the Risk Management System on manufacturing processes of panels based on bentonite nano-clay and plaster;
- Improving working conditions related to occupational safety and health;
- Alignment and compatibility of the RMM with other management systems previously implemented;
- In 2015 the company registered a new patent for fire-resistant panel containing MNMs for cladding flat surfaces of buildings elements.

<u>Task 6.3 Industrial Use Case 3: Preparation and use of construction products containing MNMs at work sites (Building construction, indoor)</u>

In IUC3 a large industrial construction company - MOSTOSTAL - implements the RMM & Toolkit into its management system and tests how to put it in use in works carried out on construction site by subcontractors. IUC3 took place in Toruń (Romania). For demonstration of SCAFFOLD utility a construction of concert hall managed by the company and built in this city was selected. In IUC3 it was decided to use a water repellent solution containing nano silicon dioxide. It was decided to use the water repellent solution in the room located in the basements of the concert hall. We wanted to use special abilities of the nano product to protect the walls from humidity. For best results of the project and exposure measurements we planned to check three different types of nano product application: by brush, roller and spray. In this task focus was put on a construction company subcontracting SMEs to carry out their work.

Figure 6.3 Construction site of new concert hall –location of IUC3 (Torun, Poland)

The company used SCAFFOLD Toolkit for initial diagnosis of the integrated H&S and environment management system regarding work with materials containing nanoparticles and to support the RMM implementation. As a result it was decided that currently used system (certified accordingly to ISO 9001, ISO 14001, PN-N-18001 and OHSAS certificates) should be complemented by results of SCAFFOLD. A new annex to the document that establishes requirements of H&S for any subcontractors has been created. This document consists of translated elements of SCAFFOLD guides.

The enterprise integrated into the OHS management system the specific nanorisks in a Health and Safety Plan in order to demonstrate the RMM criteria. Therefore, the integration of model is easy in these types of organization with OHS management systems (certified). The RMM helped the company in order to demonstrate the suitable and effectiveness of the management of nanorisks.

A quantitative risk assessment and external audit of the new system at construction site were done. The audit proved that SCAFFOLD can be quickly and with alignment, implemented in any company that is already using a management system certified accordingly to OHSAS 18001. It proved that SCAFFOLD can be quickly implemented in any company that is already using a management system certified accordingly to OHSAS 18001.

As benefits for the company:

- The company gained a vast knowledge about risk management of MNMs during IUC3. Extended information about risk assessment and risk protection can now be used for future safer work with state of art materials. It will allow the company to safely and confidently use materials that aren’t yet widely known and used on our national market. Potentially it can lower costs of use of these novel materials and add the enterprise an advantage in the very difficult and competitive construction sector. Additionally gained knowledge can be used for generating revenue from consultancy about risk protection and prevention in use of MNMs on Polish market.

- During the IUC we created a new document that will allow us to hire contractors or subcontractors for work involving MNMs. “Requirements of integrated environmental and OHS management system for work with nanomaterials” implements the Scaffold results into our current management system in the company.

Task 6.4 Industrial Use Case 4: Preparation and use of construction products containing MNMs at work sites (Civil construction, outdoor)

The objective of T6.4 was to test and validate the RMM & Toolkit in a large industrial company that is preparing and using products containing MNMs (concrete nanoSiO_2 based) in civil construction activities (outdoor workplace). The IUC4 activity was carried out at ACCIONA´s machinery workshop at Noblejas, Toledo, in Spain. In this location, a concrete ground slab containing n-SiO_2 was built. The nanomaterial involved in this activity was n-SiO_2. This type of additive is commonly added in concrete in order to modify its rheology. The nanoadditive is commonly supplied in form of aqueous suspension and mixed with the concrete in the truck mixer

In this IUC, the company staff used SCAFFOLD Toolkit for initial diagnosis of their management system regarding work with materials containing nanoparticles. In addition, the Toolkit was useful in order to understand the potential risks associated to the use of MNMs in construction, as well as the proposed models to prevent, assess and protect from these risks. Moreover it was useful to understand the functioning of the measurement equipment.

For the IUC4, the company elaborated a risk prevention plan according to the OHSAS 18001 and ISO 31000 standards and the use of n-SiO_2 was taken into account. The Risk Assessment Best Practice Guide was used as an additional tool in order to elaborate the risk prevention plan. The Risk Management Model was validated by integrating it into company´s implemented risk management system. The work was carried out according to the OHS management system implemented in the enterprise (OSHAS 18001) and the recommendations given by the Toolkit and SCAFFOLD guidelines. It proved that SCAFFOLD can be quickly implemented in any company that is already using a management system certified accordingly to OHSAS 18001.

Figure 6.4 IUC4 – Task 3: Spreading of concrete.

Benefits for the company

- Communication and awareness actions: the employees implied in the work were aware of the materials that they were handling and the associated potential risks
- Risk prevention actions: the onsite manager as well as the personnel in charge of the risk prevention plan were also aware of the potential risks of the used nanoadditive and could carry out their work more efficiently and in a safer way
- Use of new tools: the toolkit as well as the best Practices Guides are at the disposal of the all the above mentioned employees and will be used, if needed, in further works. This gives to the company the possibility to implement a new tool in its risk management system, which is specific for MNMs

<u>Task 6.5 Industrial Use Case 5: End of life of constructions products containing MNMs</u>

The objective of T6.5 is to test and validate the RMM & Toolkit in an industrial SME that develops activities related to the end of life of construction products containing MNMs. For the experimental part of IUC5, ROSSAL selected a building located in Roman (Romania). In this IUC were used fire-resistant panels containing MNMs, provided by ICECON (IUC2). Demolition activities were realized using a large diversity of specific methods and devices: 1. Drilling, 2. Demolition with hammer (1 kg), 3. Demolition with electric hammer, 4. Hand demolition (hammer + chisel), 5. Hand demolition with big hammer (10 kg), 6. Cutting (cutting disc). Finally, waste resulted was transported in the special area.

IUC	Company	Country	Size	Exposure scenario	MNM
5	ROSSAL	Romania	SME	End of life of NEP: Demolition of fire resistant panels	Nanoclay

Figure 6.5 IUC5 – Hand demolition with big hammer (10 kg)

The RMM was used by the company in all the stages available. It was very useful for ROSSAL in the improvement of his own complex of documents and procedures related with Integrated Management System.

Regarding the toolkit, it was very easy to fill the data, step by step. The checklist from the implementation stage was the main support for the internal audit performed in the company. Tools and templates for procedures and records, offered by SCAFFOLD Toolkit were very useful for the company. The company realized new documents, using the templates offered; we also compared the content of the templates available in the toolkit with the existing documents in the enterprise, in order to propose, if necessary, improvement of these ones.

In brief, the manner in which all the activities was developed – both regarding theoretical aspects and practical actions – and the results obtained, validated by the external audit and the measurements realized, offer ROSSAL enough reasons to appreciate that the objective of this task - to test and validate the RMM & Toolkit in an industrial SME developing end-of-life activities of construction products containing MNMs - was achieved.

As benefits for the company:

- For the enterprise, who has already implemented the standard OHSAS 18001 for a range of activities in the services field, but didn't have, yet, request or opportunities to work with MNMs, the implementation of the SCAFFOLD approach was the perfect occasion to check, one more time, the validity of his own Management System and to develop preventive actions in a new field.

- The company watched valorization of theoretical potential and practical experience provided by SCAFFOLD project for improving an integrated management system already certified and expanding its applicability to other activities not addressed yet: demolition of buildings containing nano-clay.

Task 6.6 RMM external audits (Third party)

Each of the IUC was subjected to an external audit. Results proved that SCAFFOLD RMM can be implemented to companies of different size, working with different MNMs at different stage of Life Cycle of nano-enabled products. It also proved the versatility of new system and its alignment to different management systems.

Task 6.7 RMM Recommendations for improvement

Based on the results of the IUC a specific set of recommendation for improvement of SCAFFOLD RMM & Toolkit was created.

1.4 POTENTIAL IMPACT AND THE MAIN DISSEMINATION ACTIVITIES AND EXPLOITABLE RESULTS

The seven Key Exploitable Results (KER) identified by the project Scaffold are: KER 1: Safer dispersions, KER 2: New formulations for safer fire retardant panels, KER 3: Safer construction products, KER 4: New device for trapping nanoparticles, KER 5: Strategies and methods for product certification, KER 6: Strategies, methods and tools for Risk Assessment, KER 7: Strategies methods and tools for OHS management and training.

According to the Plan for Use and Dissemination of the Foreground elaborated by the consortium (PUDF, deliverable D7.9), the highest expected impacts are associated with the following sectors and Key Exploitable Results (KER):

- Construction sector: KER 3 (Safer formulations for construction products: concretes, mortars, etc) and KER 2 (Safer fire resistant panels).
- Nanotechnology sector: KER1 (Safer high concentrated dispersions)
- Manufacturing collective protection systems and PPEs: KER 5 (strategies and methods to evaluate the efficiency of collective protection systems and PPEs, respiratory and dermal protection).
- OHS services (mainly for SMEs): KER 6 (Strategies and methods for qualitative and quantitative risk assessment - Control Banding and measuring) and KER 7 (Library of solutions for risk management: Risk Management Model, Toolkit, strategies and methods for health monitoring, quick guide for risk prevention, assessment, protection and management, etc).

With respect to issues of standardization, the most important impact is associated with KER 7, due to the future EN TS (CEN TC 352 / WG 3 / PG 5: IN-TS "Manufactured nanomaterials (MnMs) in the construction industry - Guidelines for occupational risk management ") focuses on risk management.

In addition, KER 6 and 7 also provide significant impacts for future policy on occupational exposure to nanomaterials, connected with the directives 89/391 / EEC - OSH "Framework Directive", 98/24 / EC - Risks related to chemical agents at work and 2004/37 / EC - carcinogens or mutagens at work, among others.

For any additional information related to the exploitation of project results (KERs) are contained in the PUDF (deliverable D7.9).

Impact on industry and society

Employment in nanotechnology will surpass a predicted 10 million jobs worldwide in 2015. This will account for 11% of the employment in the manufacturing sector. Currently, the direct employment in nanotechnology is estimated at 300 000 to 400 000 jobs in the EU, with an increasing tendency. The European construction industry (2013) employed 13,9 million people - 6,4 % of total employment and 29 % of industrial employment - in 2,9 million enterprises, most of which – 95 % - are SMEs with less than 20 operatives. In parallel, construction industry shows one of the worst occupational safety and health records in Europe.

In this context, implementation of SCAFFOLD practical and cost effective strategies, methods and tools for reduction of worker exposure to MNMs will produce a very important impact on companies and workers, in terms of OHS improvement (KER 6,7). A proper management of MNMs based on SCAFFOLD approach will preventively contribute to avoid potential chemical accidents and diseases at work, contributing to reach the strategic objectives defined by the new OHS European Framework adopted by the EC. This preventive approach will produce parallel benefits by reduction of non-safety bill both in construction companies and in the whole European industry.

Impact on SMEs - “Thinking small first”

SMEs is a highly relevant issue in the construction industry, representing 99.9% of all enterprises in the sector. In total, there are 13.1 million people employed in SMEs of the construction industry. SMEs are more vulnerable to occupational risks and in particular those companies working in dangerous sectors like construction. SMEs account for 82% of all occupational injuries and about 90% of fatal accidents. In total, SMEs account for around 80% of all occupational diseases caused by chemical agents.
This picture means that implementation of the SCAFFOLD framework on SMEs will have a very relevant impact on the European construction industry (KER 6,7). To take this significant issue into account, SCAFFOLD produced a specific approach for SMEs by customizing both the RMM and toolkit. Subcontracting, identified as an emerging risk in the sector, has been also a significant topic considered by the project. A relatively large, and increasing percentage of subcontracted SMEs (23 %) recognise the obligation to fulfil a safety management standard (e.g. OHSAS 18001) imposed by their clients. Increasing awareness the part of the contractors about occupational risks of MNMs will bring new requirements for SMEs. Implementation of SCAFFOLD RMM will provide SMEs with a competitive advantage impacting positively on the sector.

Impact on the market

Products underpinned by nanotechnology are forecast to grow from a volume of 200 bn € in 2009 to 2 trn € by 2015. These applications will be essential for the competitiveness of a wide area of EU products in the global market. A critical issue regarding the success of any method for nanomaterials and nano-enabled products manufacturing is its cost effectiveness. But a second market requirement is to guarantee safety of the product along life cycle. In this sense, SCAFFOLD results very promising since it allows the use of reasonably low cost raw materials and, furthermore, this production method results in important increase of product safety and savings in energy and cost (KER 1,2,3).

Nano-enabled products

As an example, the annual US demand for nanocomposites will more than double by 2011 reaching 130,000 tonnes. By 2025 it is expected that nanocomposites will be a 6.5 billion € market, with volumes approaching 2.2 million tonnes. It is predicted that among the thermosets, nanocomposites will make the strongest impact as enhancements for reinforced polyester and epoxy resins; noting that 'construction will also emerge as a significant market. Although thermoplastics will remain the major platform, 'nanocomposites are expected to penetrate a significant portion of reinforced thermoset polyester resin systems' reaching 20% of the total demand (almost half a million tonnes) by 2025. Related sources suggest that 360 million pounds of nanoadditives will be required by 2020 at a value of 1.4 billion €, over half of which will be used to purchase CNTs. It is clear that unsaturated polyester nanocomposites will dominate the other thermosets with construction and automotive both being major users. Indeed, the requirement for nanocomposite based UP resins in the construction and motor vehicles markets will increase fourfold between 2011 and 2016. Therefore, it is imperative that the HSE issues (safe product design, safe manufacturing, OHS risk management, compliance with OHS regulations, etc) surrounding these materials and sectors in particular are adequately solved and risk prevention strategies put in place rapidly. SCAFFOLD may play an important role in this sense (KER 1,2,3).

Occupational Health and Safety Management Systems (OHSMS)

OSHAS 18001 is the worldwide reference in occupational health and safety management. The number of certified companies has increased dramatically from 2003. In three years (from 2007 to 2009) the number increased by 73% in the world. A recent report shows how the penetration on this standard is higher amongst SME´s; in fact, the study shows that 81% of the companies were SMEs, 52% between 50 and 250 workers and 29% with less than 50 employees.

The SCAFFOLD project could then have a greater impact in European SMEs (KER 7). Regarding the construction, this sector is leading the implementation of OHSAS (37%), showing the commitment of the construction companies, especially SMEs, to the improvement of labour safety in Europe. It is also important to ensure that the new RMM is fully compatible with OSHAS and the worldwide-recognized management systems Standards EN-ISO 9001 and EN-ISO 14001. In fact, according with the above-mentioned study, 97% of the companies certified according to OSHAS 18001 where already certified according to ISO 9001 and 91% according to 14001. These figures show the importance of the compatibility in the integration of the environmental, quality and labour safety issues in the organizations.
Taking into account the real evolution of the OSHAS 18001 certification market and its probable tendency we can make some conclusions:

1 Certification market for OSHAS 18001 will be twice its current size in two years (in 2012 more than 100.000 companies will be certified).If the tendency continues, 80% of those companies will be SMEs.
2 This means that, estimating a cost of around 6.000-10.000 € per company (4.000-6.000 € for system implementation and 2.000-4.000 € for certification), the market for OSHAS 18001 in one and a half year will be of around 400-1.000 M€ (320-800 M€ will only for SME).It is easy, from a very conservative perspective, to estimate that market will be doubled again by 2020, which would easily represent a 2.000 M€ market only for OSHAS 18001.
3 Considering the current evolution of nanoparticles and nanomaterials, and also considering the expected evolution of OHSAS 18001, the creation and commercialization of the RMM model could have a great impact in the market, specially for SMEs.

Regarding the RMM, is expected that at least 10% of the companies are interested in implementing and certifying the new model, considering that the RMM will be fully compatible with OHSAS and with other management systems and that, and because of its compatibility, the certification costs associated to the RMM will be very low, when done in conjunction with OHSAS. The model will be very attractive for the market because for two main reasons: 1) The RMM is associated with three key issues, ISO 31.000 (risk management model), OHSAS 18001 and nanocompounds and nanoparticles, a sector which is expanding dramatically and 2) the RMM (and specially the toolkit) is associated with SMEs, a sector in which is traditionally harder to certify and harder for the companies to incorporate management systems.

With over 127 countries currently using OHSMS standards, there's a worldwide need to harmonize health and safety management systems using an international standard and share best practices. Inspired by the well-known OHSAS 18001, ISO is currently developing ISO 45001. There are 50 countries and international organizations, including the International Labour Organization, involved in this work. The future standard will also be aligned with ISO 9001 and ISO 14001. The new standard is expected to be published in late 2016.

The publication of this new standard may introduce new items on the market and promote the migration of certifications from OSHAS 18001 to ISO 45001. In any case, elements developed by the project SCAFFOLD (KER 7) can be easily integrated in the new standard. In this regard, depending on the evolution of the new ISO project, the future EN TS (CEN TC 352 / WG-3 PG5 Scaffold), currently under development, could also be adapted to the high-level structure of ISO 45001 to facilitate integration.

Impact on European policies and regulations

The new Strategic Framework on Health and Safety at Work 2014-2020 adopted by the European Commission includes nanotechnology and practical support to small and micro enterprises as two of the seven strategic objectives. In this sense some objectives tangibly impacted by SCAFFOLD will be: 1) the development of new methods for identifying and evaluating new potential risks and 2) the support SMEs and the high-risk sectors - like construction - in the implementation of the legislation in force and its adaptation to changes in the workplace (KER 6,7). On the other hand, the SCAFFOLD project will positively contribute 1) to reach some of the objectives defined by the Action Plan for Construction of the Lead Market Initiative (LMI), 2) to support nanosafety issues of the European policy on nanotechnology, 3) to support the Innovation Strategy for Europe by introducing innovation in the core of construction sector, contributing to become it in an innovation-friendly sector, enhancing Europe's global economic competitiveness in a global market.

SCAFFOLD will contribute positively on future European Regulations by providing new information to elaborate better regulations about issues related to safety of MNMs (products and OHS issues) and for supporting compliance with current legislation requirements. Main topics to be addressed will be:

- *Future strategy for management the occupational exposure to MNMs in the construction industry*. The SCAFFOLD project has deployed a specific task to build a proposal in this field (KER 7). The proposal is aligned with the new European OHS framework and coherent with the roadmap for the construction sector developed by the project. The document includes proposals for future regulations in the field of the occupational exposure to nanomaterials (e.g. OELs).

- *Product safety*: SCAFFOLD developed focused research on safer new products for construction and produced a specific guideline for Risk Prevention (KER 7). This guideline can be used by manufactures to guide safe-by-design approaches for future construction products falling under Council Directive 89/106/EEC. A second guideline focused on Risk Protection (KER 7) may also used by manufactures of PPE s (Directive

89/686/EEC). Documentation is addressed to those involved in writing European regulations and technical specifications on construction products and PPEs, in particular those connected with the necessary information required for the CE marking.

- *<u>Health and Safety at work</u>*: SCAFFOLD RMM and tools (KER 6,7) will provide relevant support allowing construction industry to consistently identify and control its occupational nano-risks, facilitating HSE legislative compliance; in particular with the Framework Directive 89/391/EC and other related Directives (e.g. 98/24/EC - risks related to chemical agents at work, 92/57/EEC, 89/656/EEC, 89/654/EEC, 89/655/EEC) and connected legislation (e.g. REACH). Scaffold results can be also used as relevant information for future OHS legislation in the field of risks related to the occupational exposure to nanomaterials at work

Standardisation and other impacts

Standardisation is a highly relevant issue in this sector. In the European Committee for Standardisation (CEN), the construction sector covers around 3,000 work items on product standards and test methods. Of these, about 500 standards will be harmonised under the Construction Products Directive (89/106/EEC). The results of the project in the areas of new safer products (safe-by-design) (KER 1,2,3) and testing PPEs (KER 5), can be used to promote the development of European standards addressed to reduce potential barriers that might cause an increase of the time to place in the market of new construction nano-products (mortars, coatings, etc) and PPEs. In addition, SCAFFOLD project will also provide innovative inputs for new/improved OHS standards in the field of OHS management and workers protection against MNMs. The future EN TS (CEN TC 352/WG3-PG5) on Risk management in the construction sector launched by the project is a very good example (KER 7).

- <u>Strategic Research Agendas (SRAs) of the European Technology Platforms (ETP).</u>The SCAFFOLD approach agrees in particular with the SRAs of Construction (ECTP), Industrial Safety (ETPIS) and the vision of the Nanofutures, contributing positively to reach their research objectives.

- <u>EU - nano-safety cluster (NSC)</u>. Members of SCAFFOLD consortium have close relationships with ongoing/previous research projects within the umbrella of the EU - NSC. This position will guarantee synergies establishment, close coordination among activities, mutual reinforcement of project impacts and finally a significant contribution to the advancement of the EU-NSC cluster goals and agenda beyond of the end of the project. To maximize SCAFFOLD impact, the project will establish future activities to disseminate the results. In addition, contacts with non-EU partners (USA) (e.g. UMN-PTL, NIOSH, Center for Construction of US) have been established and will be intensified after the end of the project. A first step is the development of the Scaffold Handbook.

Dissemination and exploitation activities

The main **dissemination and activities** performed in the SCAFFOLD Project are the following:

- Promotion and dissemination through the **project website** (http://scaffold.eu-vri.eu/)

- Promotion and dissemination through the **EU-Nanosafety cluster website** http://www.nanosafetycluster.eu/eu-nanosafety-cluster-projects/seventh-framework-programme-projects/SCAFFOLD.html
- **5 scientific publications**, including the SCAFFOLD Handbook currently in press (Ed. AENOR, English version)
- **5 non-scientific publications**, including Horizon 2020 Magazine and NSC Compendiums & Newsletters
- **Participation in 22 Conferences** (20 oral presentations and 15 poster), among other:
  - nanoLCA 2012 (May 2012, Donostia, Spain)
  - SENN2012 (Helsinki, Finland, October 2012)
  - NANOSAFE 2012 (November 2012, Grenoble, France)
  - nanoLCA 2013 (May 2013, Barcelona, Spain)
  - 5th iNTeg-Risk Conference (May 2013, Stuttgart, Germany)
  - EuroNanoforum 2013 (June 2013, Dublin, Ireland)
  - European Aerosol Conference EAC2013 (September 2013, Prague, CZ)
  - Industrial Technologies 2014 (April 2014, Athens, Greece)
  - Nanotox 2014 (April 2014, Antalya, Turkey)
  - European Aerosol Conference EAC 2014 (April 2014, Karlsrue, Germany)
  - Smart materials and surfaces conference (August 2014, Bangkok, Thailand)
  - Nanosafety Forum for Young Scientists (October 2014,Syracuse, Italy)
  - Standards your innovation bridge (October 2014, Brussels, Belgium)
  - NANOSAFE 2014 (November 2014, Grenoble, France)
  - European conference on nanotechnologies (December 2014, Brussels, Belgium)
  - CompIC 2015 - Composites in Construction (February 2015, Amsterdam, Netherlands)
  - IMAGINENANO 2015 (March 2015, Bilbao, Spain)
  - SENN 2015. (April 2015, Helsinki, Finland)
  - CEN TC 352 Meeting. CEN/TC 352/WG 3/PG 5 – SCAFFOLD (April 2015, Ispra, Italy)
- **Organization of 7 Workshops and Conferences**:
  - Workshop on occupational nanosafety: Managing occupational risks associated with nanomaterials (in the framework of ORP2012 Congress) (May 2012, Bilbao, Spain)
  - Integration of Standardization in Research and Innovation Projects (July 2012, Madrid, Spain)
  - Nanocomposite on their way to commercial success (September 2013, Granada, Spain)
  - NANOSAFE 2014 – Delphi workshop: Risk Assessment and Risk Protection (November 2014, Grenoble, France)
  - Nanosafety challenges and management tools work in the Basque company OHS (December 2014, Bilbao, Spain)
  - Delphi Workshop: Guide for Risk Management (March 2015, Madrid, Spain)

- SENN 2015 - SCAFFOLD Final Conference (April 2015, Helsinki, Finland)

From top to bottom and left to right: 1) Delphi Workshop on risk Assessment and risk Protection organized in NANOSAFE 2014 (Grenoble), 2) European Conference on Nanotechnologies (Brussels, 2014), 3) Sectorial Social Dialogue Committee for Construction, working group H&S (Brussels 2015), 4) SENN 2015 (Helsinki).

- **Participation in 5 exhibitions/fairs**:
    - IMAGINENANO 2013 - Bringing together Nanoscience & Nanotechnology (April 2014, Bilbao, Spain)
    - Industrial Technologies 2014. (April 2014, Athens, Greece)
    - Technical conference and Special Textile Innova Tex 2014 International Fair (October 2014, Lodz, Poland)
    - Standards your innovation bridge. (October 2014, Brussels, Belgium)
    - Bau 2015 (January 2015, Munich, Germany)
- **Participation in events organized by the NMP Programme**:
    - Nanosafety Cluster Review meeting (December 2014, Brussels, Belgium)
- **Participation in 2 meeting of the Sectorial Social Dialogue Committee for construction.** Working group Health & Safety (April 2014 and March 2015, Brussels, Belgium)
- **Participation in cluster activities**:
    - nano E2B cluster (May 2012, Crete, Greece)
    - NSC meetings: Helsinki 2012, Prague 2013, Birmingham 2013, Antalya 2014, Syracuse 2014, Helsinki 2015.
- **Participation in workshops on Harmonization of the Measurement Strategies** for the Assessment of Exposure to Manufactured Nano objects, agglomerates and

aggregates (NOAA) (Global Measurement Harmonization Workgroup): Helsinki 2012, Nagoya 2013, Grenoble 2014, Helsinki 2015.
- **Liaison** with CEN TC 352
- **Participation in CEN TC 352 meetings**.
- Dissemination within the members of related **European & National Technology Platforms** (ETPIS / PESI, ETPC)
- **Brochures and leaflets**:
  - Standards your innovation bridge (CEN)
  - Nanomaterials in the construction industry. Guidance for protecting and monitoring health of workers (FIOH)

With regard to **exploitation actions**:

- **Patent**, ref. A/00284/2015 Composition and technological process for fire-retardant panels based on plaster and nanoclay (applicant ICECON)
- **Future standard** EN TS "Manufactured nanomaterials (MNMs) in the construction industry — Guidelines for occupational risk management"

Exploitation of the results

The project deliverable D7.9 - Industrial Exploitation Plan - encapsulates the Plan for the Use and the Dissemination of Foreground (PUDF). This document summarizes the strategy and the concrete actions for the protection, exploitation and dissemination of the results generated by the project. All the necessary elements to ensure the adequate exploitation of the project results are contained in this document: 1) List, description and impact of Key Exploitable Results (KER), 2) Status of IPR, 3) Strategy and concrete actions for exploitation of the project's results and, 3) Risks, and finally 3) Dissemination plan.

According to PUDF, seven Key Exploitable Results (KER) were identified by the project:

- KER 1: Safer dispersions
- KER 2: New formulations for safer fire retardant panels
- KER 3: Safer construction products
- KER 4: New device for trapping nanoparticles
- KER 5: Strategies and methods for product certification
- KER 6: Strategies, methods and tools for Risk Assessment
- KER 7: Strategies methods and tools for OHS management and training

The purpose of the commercial exploitation of these project results is to provide: 1) New safer products for the construction industry and other industrial sectors (KER 1-3), 2) New technologies for manufacturers of particle measurement equipment (KER 4) and finally, 3) New advanced services in the field of testing consulting, training and certification, for the construction industry in particular and the European industry in general.

In order to ensure a successful exploitation, each partner identified its exploitation actions. This information is encapsulated in the PUDF. In brief, the following table summarizes the foreground to be exploited and by whom.

Partner	KER1	KER2	KER3	KER4	KER5	KER6	KER7
TECNALIA							
CEA							
DEMOKRITOS							
CIOP-PIB							
ACCIONA							
AENOR							
MOSTOSTAL							
ROSSAL							
TECNAN							
NETCOMPOSITES							
ICECON							
EU-VRi							
FIOH							

Table 1.4.1 Foreground to be exploited (KER) and partners involved.

IPR exploitable measures taken or intended

For the success of the SCAFFOLD project, all project partners agreed on explicit rules concerning IP ownership, access rights to any Background and Foreground IP for the execution of the project and the protection of intellectual property rights (IPRs) and confidential information before the project started. Therefore, such issues were addressed in detail within the Consortium Agreement between all project partners.

The Parties agreed to respect individual Intellectual Property Rights (IPR). The SCAFFOLD partners agreed since the proposal preparation stage that foreground is the property of the beneficiary that has carried out the work that has generated that foreground. For the cases in which several beneficiaries have carried out work in a joint manner and have generated foreground where their respective share of the work cannot be ascertained, they will have joint ownership of such foreground. They will establish an agreement regarding the allocation and terms of exercising that joint ownership.

The foreground resulting from the project is owned by the participant generating it. In case of joint ownership of Foreground, a separate written agreement shall be concluded among the Parties concerned.

For additional information, the background and foreground status of the SCAFFOLD consortium have been collected and updated in PUDF (Tables 3 and 4).

Further research

Only some nanomaterials, applications and scenarios have been investigated by SCAFFOLD project in construction. The list of products containing nanomaterials is growing. Consequently more experimentation in real scenarios is required to consistently validate the OHS strategies, methods and tools developed by the project (e.g. strategies and methods for qualitative and quantitative risk assessment involving nano-enabled products, effectiveness of the protection systems, etc.)

In addition, the SCAFFOLD approach could be positively implemented and validated in other European industrial sectors, in order to provide cost effective solutions to risk management that might arise with the use of nanomaterials and nano-enabled products. All this requires further research.

5 ADRESS OF PUBLIC WEBSITE OF SCAFFOLD PROJECT

The URL direction of the SCAFFOLD project website is: http://scaffold.eu-vri.eu/

6 CONTACT DETAILS FOR SCAFFOLD CONSORTIUM

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