Project title:

Development of a Best Practices Guide for the Safe Handling and Use of Nanoparticles in Packaging Industries

Project Acronym: **NanosafePACK**

Grant Agreement: **286362**

Attachments to the Publishable Summary of the Project

Date of preparation:
29/01/2015

Nature of the Document Public
PUBLIC

Table of Contents

1. Contact Details and List of Partners

The following table shows the list of participants in the project, type of organization and location:

Table 1. List of Participants

Participants		Acronym	Member State / City	Type
Tecni-Plasper, S.L.		PLASPER	Spain / La Roca del Vallès (Barcelona)	SME
Tec Star S.r.l.		TECStar	Italy / Campogalliano (Modena)	SME
European Plastic Converters		EuPC	Brussels / Belgium	European SME Association
The Portuguese Association of Plastic Industry		APIP	Portugal / Lisbon	National SME Association
Centro Español de Plásticos		CEP	Spain / Barcelona	National SME Association
Instituto Tecnológico del Embalaje, Transporte y Logística		ITENE	Spain / Paterna (Valencia)	Research Organization
Institute of Occupational Medicine		IOM	United Kingdom / Edinburgh	Research Organization

The table below includes the directory of the main persons involved in the execution of the project per partner:

Table 2. Directory of people involved in this project.

First Name	Last Name	Affiliation	Address	e-mail
Angel	Lozano	Centro Español de Plásticos	Enrique Granados, 101	alozano@cep-inform.es
Wouter	Geurts	European Plastic Converters	Avenue de Cortenbergh, 71	Wouter.geurts@eupc.org
Antonio	Furfari	European Plastic Converters	Avenue de Cortenbergh, 71	Antonino.Furfari@eupc.org
Maria Estela	Izquierdo	European Plastic Converters	Avenue de Cortenbergh, 71 1000 Brussels - Belgium	Maria.Estela.Izquierdo@eupc.org
Isabel	Ferreira de Costa	The Portuguese Association of Plastic Industry	Edificio Libersil - Torre B, Rua de S. José, 35 2ºC, 1150-321 Lisboa	isabelfcosta@apip.pt
Jose Luis	Romero	Tecni-Plasper, S.L.	Pol. Ind. Font de la Parera. Bonaventura Aribau, s/n La Roca del Vallès (Santa Agnès de Malanyanes), Barcelona Spain	JoseLuis.Romero@plasper.com
Lorenzo	Calabri	Tec Star , Srl	TEC Star Srl Viale Europa, 40 41011 Campogalliano (MO) - Italy	calabri@tec-eurolab.com
Carlos	Fito	Packaging, Transport and logistics research center	Albert Einstein, 1 CP.46.980 Paterna (Valencia) – Spain	cfito@itene.com
Eva	Araque	Packaging, Transport and logistics research center	Albert Einstein, 1 CP.46.980 Paterna (Valencia) – Spain	earaque@itene.com
Steve	Hankin	Institute of Occupational Medicine	Research Park North / Riccarton UK-EH14 4AP Edinburgh United Kingdom	steve.hankin@iom-world.org
Craig	Poland	Institute of Occupational Medicine	Research Park North / Riccarton UK-EH14 4AP Edinburgh United Kingdom	craig.poland@iom-world.org

2. Publishable summary

2.1. Background and concept of the project

The use of nanoparticles in packaging manufacturing is an area with a broad applicability, providing the opportunity to develop new and innovative packaging materials, principally derived from the manufacture of nanocomposites, polymers reinforced with materials and/or particles that have one or more dimensions of the order of 100 nm or less, commonly called nanofillers or nano-reinforcements.

The use of these nanometer sized materials, commonly metal oxides, nanoclays, carbon nanotubes and other fillers like metallic nanomaterial (NMs), improve barrier and mechanical properties, chemical stability and other functional properties of the reinforced polymers e.g. photocatalytic, optical, electrical or thermal stability. These nanofillers are introduced in polymer at rates from 1% to 10% (in mass), being incorporated in addition to traditional fillers and additives, and eventually traditional reinforcement fibres such as glass, carbon or aramid fibres.

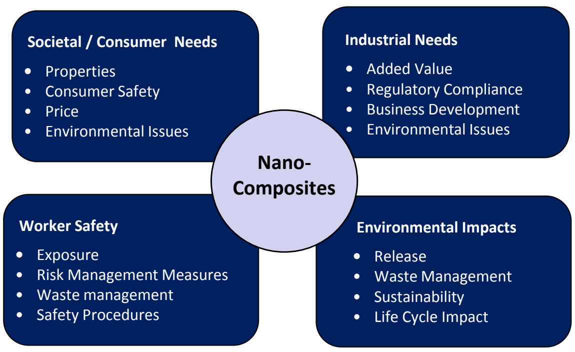
These new properties and the expected development in the near future results in a continuous growth of nanocomposites in the market. Due to the new properties addressed by the use of nanofillers, the market seems to be very promising, with a potential greater than $20 billion by 2020 and a production close to 5 million tons by 2015 in the global nanocomposite market.

The manufacture of nanocomposites brings new opportunities to the European packaging industry in general, nonetheless, along with the benefits there are also concerns that a variety of the characteristics possessed by nanomaterials, such as small size, high aspect ratio, shape, surface reactivity or dustiness, can lead to a gamut of adverse effects in humans and environment.

In the specific case of the nanocomposite industry, several studies show a substantial release of ENPs during the production process. The most common process to commercially produce nanocomposites is the melt-blending compounding, where the airborne particles released are of particular risk, as they can readily enter the body through inhalation.

Additionally, once placed on the market, the polymers are susceptible to physicochemical factors such as photodegradation or abrasion, such that, NPs imbedded in the polymer may potentially be released into the environment. Such a release might have an effect to the consumers and the environment and present a barrier on their potential uses.

These aspects have a special relevance for the food packaging industry, where it has raised a number of safety, environmental, and regulatory issues. Therefore, the **safety issues related to workers and consumers have to be faced** prior to the investment in new resources from the SMEs. The figure on the right shows the main aspects to consider when placing nanocomposites on the market.



In view of the current situation, the project stemmed from the need to ensure the safety of workers dealing with NPs and to guarantee the safety of the nanocomposites placed on the market, avoiding endangering consumers' health and the environment.

The solution and main goal proposed by the NanoSafePACK project was the **development of a best practices guide to allow the safe handling and use of nanoparticles in packaging industries**, considering integrated strategies to control the exposure to nanoparticles in industrial settings and provide the necessary data to minimize and control the potential release of nanoparticles from the nanocomposites placed on the market.

Moreover, significant regulatory concerns from the European Commission have arisen about unforeseen risks likely to arise from nanocomposites, so that, the project worked to provide legislators and industry with new knowledge for appropriate risk management and decision making, creating the basis to meet the current regulation related to the use of nanometer range additives, considering as key priority the compliance with the following regulations:

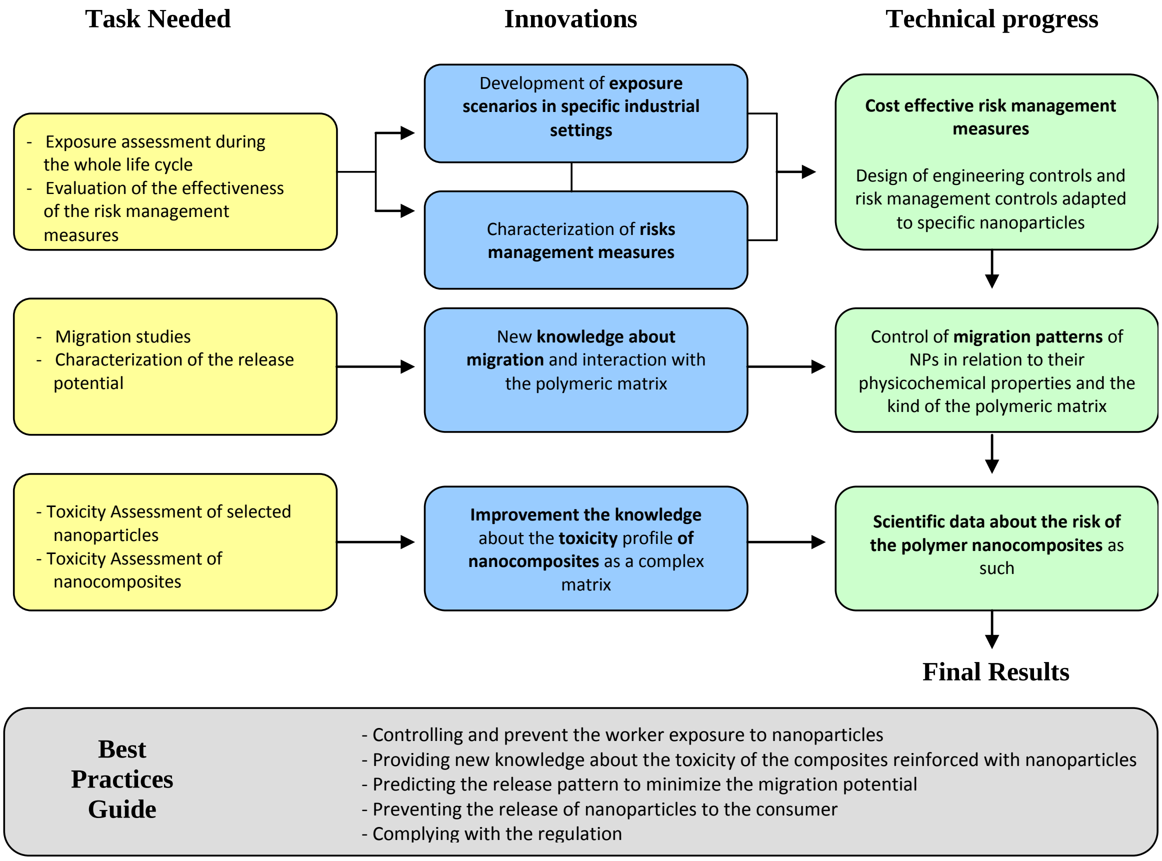
- Regulation EC/1935/2004 (contact with foodstuffs)
- Regulation (EC) 10/2011 on polymeric materials intended to be in contact with foodstuffs
- Regulation (EC) 282/2008 on recycled plastic mat. / articles
- Regulation (EC) No 450/2009 (NPs included)
- REACH Regulation

To achieve this goal, a complete hazard and exposure assessment was conducted to obtain necessary new scientific data about the safety of polymeric nanocomposites. The work focused on a selected set of relevant NPs and polymers for the packaging sector.

Full characterisation was carried out, followed by an exposure measurement in order to identify and quantify any potential airborne particle release in the production and processing activities. A comprehensive hazard assessment allowed the evaluation of effects on human and environmental models, including the characterization of the potential NPs migration and release index.

Results from the exposure and hazard assessment studies were used to compile a risk assessment of the use of nanoparticles in the packaging industry. An evaluation of the effectiveness of risk management measures was undertaken in order to select and design practical and cost effective strategies, which will be easy to implement by the industry. In addition, as part of this assessment we conducted a life cycle assessment of nanocomposites, by evaluating their impacts during the steps of manufacture, use and disposal.

The overall concept of the project is shown in the figure below:



2.2. Main Objectives

The main objective of the NanoSafePACK project was to develop a **best practices guide to allow the safe handling and use of nanomaterials in packaging industries**, considering integrated proven strategies to control the exposure to nanoparticles in industrial settings, and provide the SMEs and industrial users with scientific data to minimize and control the nanoparticles release and migration from the polymer nanocomposites placed on the market.

In the consumer stage, we have generate reliable data on the hazard properties of the most common nanofillers, defining a list of nanofillers and polymeric matrices that can be considered safe on the basis of the tested toxicological and migration potential.

Overall, the features of the main outcomes of the project are depicted below:

In detail, it has been possible to produce the following final results:

- Edition of the NanoSafePack Best Practices guide by November 2014 in English, Spanish, Portuguese, French and Italian, including the publication in paper and PDF version. Also a mini-guide intended to introduce the complete Guide and main outcomes people can find in it has been edited.
- A complete description of the adverse effects posed by the use of nanofillers based on the migration potential and the physicochemical, toxicological and ecotoxicological properties of the most common nanofillers for packaging applications.
- A complete description of the current exposure scenarios across the nanocomposites life cycle, including an in depth description of the existing operational conditions, efficient RMMs and measured exposure levels.
- New information on the release rates to air, surface fresh and marine water, waste water and soil for each relevant stage on the life cycle.
- New knowledge on the airborne behaviour of the target NMs, including new data on their aggregation/agglomeration patterns and deposition factors under the specific operative and environmental conditions of use presented in the nanocomposites production facilities.
- New data on the recyclability and compostgability of polymer based composites reinforced with nanofillers.
- A structured compendium of free workshops to support the training of end users and stakeholders in the use and implementation of the Best
- A set of informative material to disseminate the project actions at a Regional, National and European level.

2.3. Expected Impacts

Regarding the impact of the project, it is expected a high socio-economic impact derived from the improvement of the consumer acceptance of novel technologies aimed at developing new advanced products containing ENMs, the promotion of the business opportunities and the sustainable development of the nanocomposite industry.

It should be noted that NanoSafePack project overcome the current barriers for consumer acceptance, improving the current knowledge on the potential exposure across the nanomaterials life cycle and defining proven measures to control and manage the risks. In this regard, convincing potential customers of the safety and sustainability of the nanocomposites sector will improve the acceptance of this kind of products by the society, being a key priority for nanomaterials manufacturers and nanocomposite suppliers in the shor-term.

In economic terms, the improvement in the safety of the production process and the development of safe and eco-friendly nanocomposites will improve the business opportunities of the EU nanocomposites industry, as well as open new business opportunities to the SMEs involved in the use of nanofillers. New nanostructured products will offer good opportunities due to their enhanced environmental acceptability and superior performance traits.

Similarly, the enhancement of the knowledge in terms of hazard profile, exposure potential and protection measures will promote the sustainable growth of the nanocomposites industry, being able to generate new jobs that directly or indirectly will support the further development of the local and regional economies. Moreover, improved worker and consumer safety have obvious economic benefits for the EU with respect to healthcare provision.

Finally, the participation of enterprises in the project implementation and the direct application in case studies will help in the dissemination of the project results, providing the industrial stakeholders and the general public with appropriate knowledge to successfully control the risks posed by the use of nanomaterials.

3. Compendium of Photographs illustration and promoting the work

3.1. Project Meetings

The following pictures were taken during the final meeting of the project held in Brussels last November, 2013.

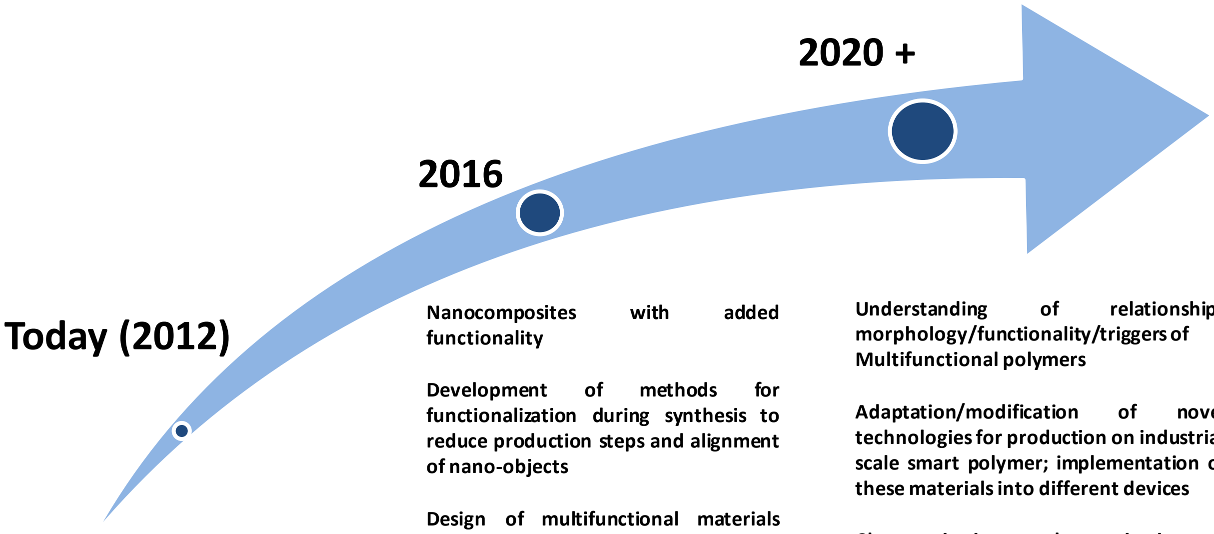
Figure 1. Project consortium during the final meeting in the facilities of the European Plastic Converters association (EuPC). From left to right: Angel Lozano (CEP), Sheona Read (IOM), Lorenzo Calabri (Tec Star), Isabel Costa (APIP), Steve Hankin (IOM), George Boulougouris (ITENE), Ruta Tamosiunaite (EuPC), Jose Luis Romero (Coordinator – Plasper), Carlos Fito (ITENE).

Figure 2. Photograph of the Project Consortium during the kick of meeting

3.2. Scientific and Technical Activities

3.2.1. Identification of the Nanotechnology applications in packaging

The figure below shows the conclusions of the industrial partners regarding the current situation and the foreseeable development of the nanocomposites industry in the medium and large term



Barrier packaging using silicates

Structural & physical enhancement of polymers:

The incorporation of organically modified montmorillonite, TiO2 or SiO2 improve mechanical properties, transparency, crystallinity, gas impermeability and flame resistance

Successful technical development of polymer nanomaterials for food packaging

Nanocomposites commercially available, and applied to the Automotive and food packaging industries

Biodegradable polymer based nanocomposites

Nanocomposites with added functionality

Development of methods for functionalization during synthesis to reduce production steps and alignment of nano-objects

Design of multifunctional materials tailored for different needs

Development of combined active/passive oxygen barrier systems

Scaling-up

Nano-objects integration In surface engineering

Enhanced fire properties

Viable robust recycling, lifecycle analysis, self or nano-reinforced polymers

Adaptation of machines and process parameters to maintain functionalities

Cost effective industrial scale technologies for synthesis and technologies for dispersion/exfoliation (extrusion)

Understanding of relationships morphology/functionality/triggers of Multifunctional polymers

Adaptation/modification of novel technologies for production on industrial scale smart polymer; implementation of these materials into different devices

Characterization and monitoring of materials structure, properties and functionalities

Materials modelling, thermal simulation and process design

Development of Green Polymers

Combinations of nanofillers

- Organo-modified nanoclays in combination with metallic hydroxides,
- Organo-modified nanoclays in combination with phosphorous compounds
- Nano-hydroxides and nano-oxides in combination
- Carbon nanotubes in combination with metallic hydroxides.

Figure 3. Key technologies and expected developments of the nanocomposite industry

3.2.2.Samples of the Target Nanofillers – Electron Microscopy Images

The following figures shown the electron microscopy micrographs of the target nanofillers used for packaging applications.

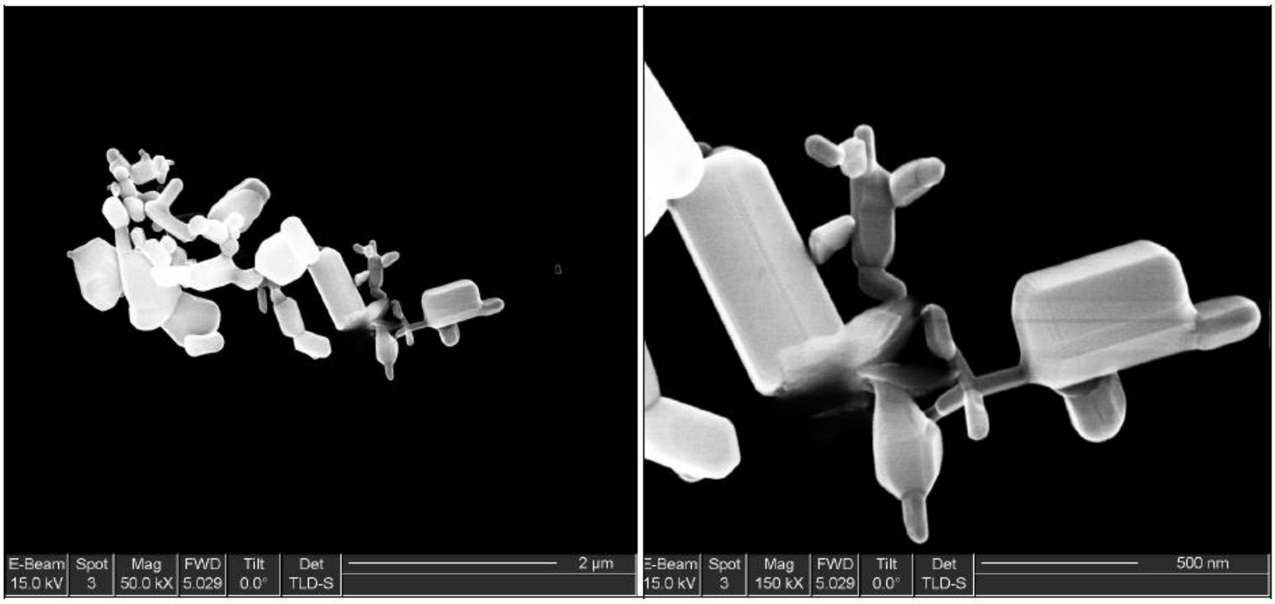
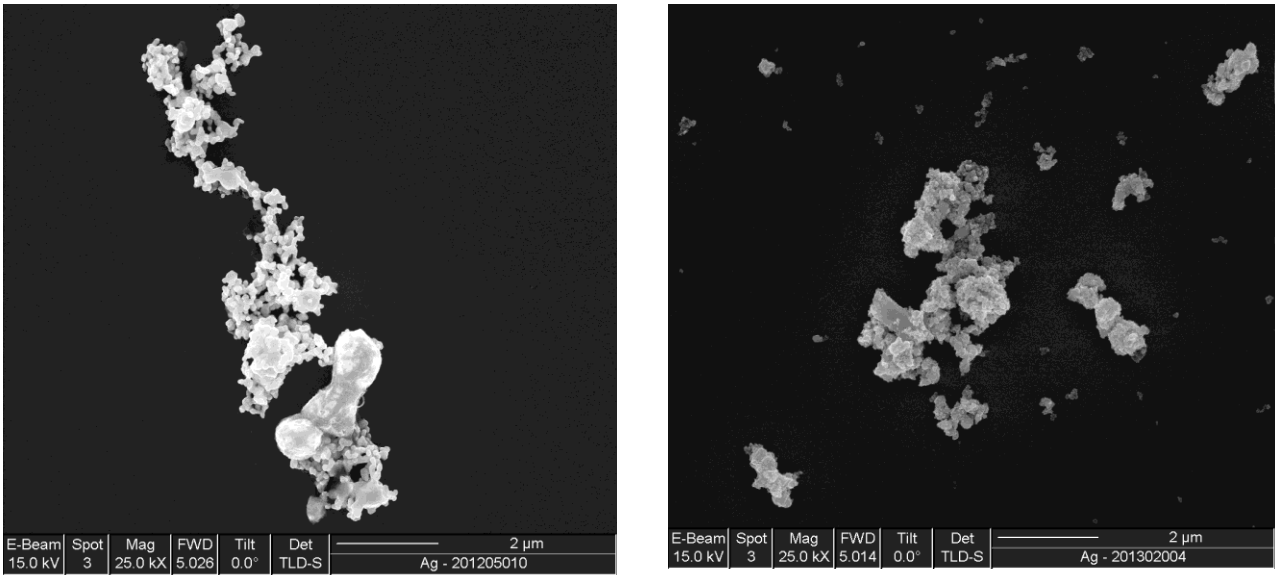


Figure 4. ZnO Nanofillers from Tec Star



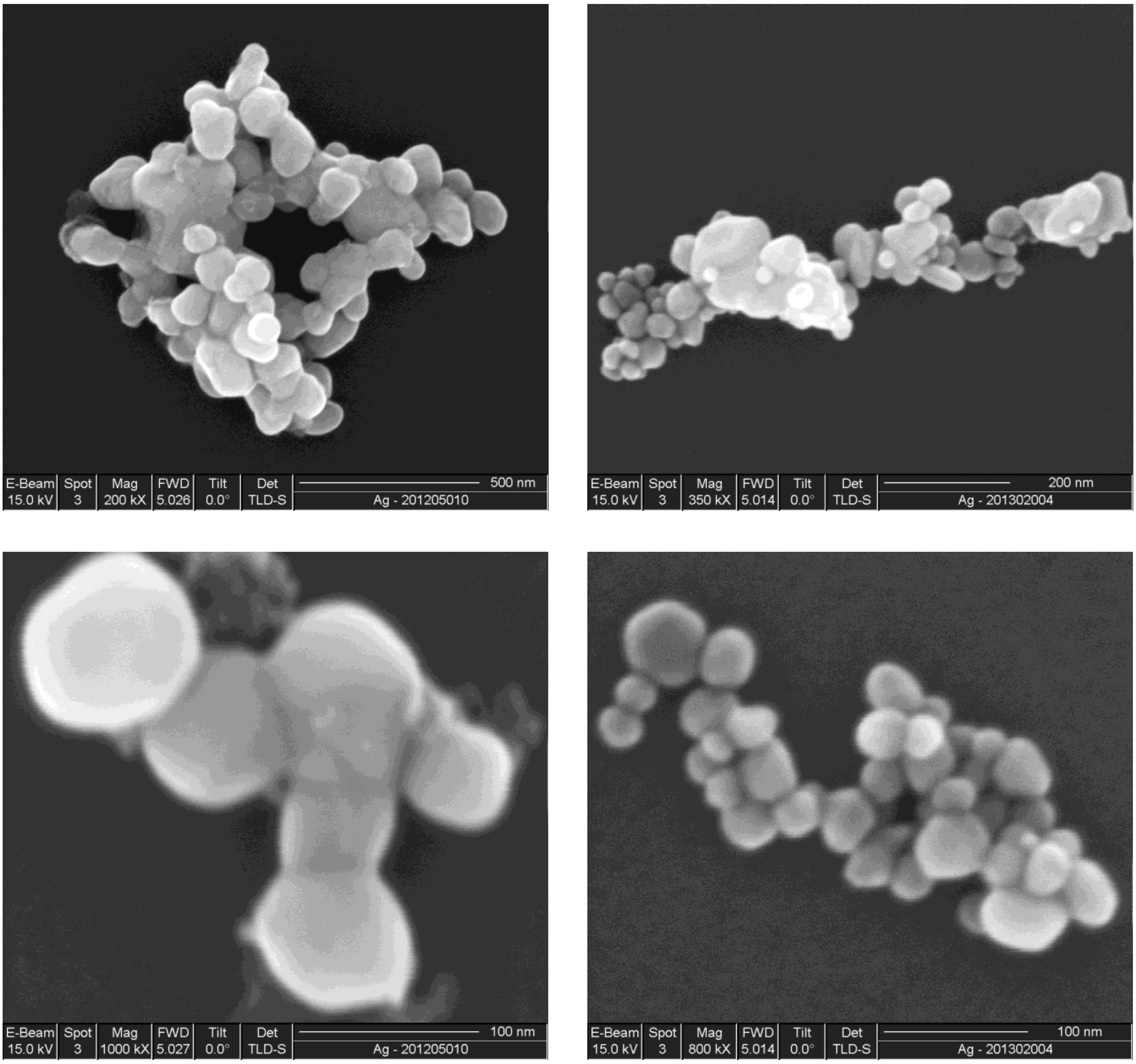


Figure 5. Silver Nanofillers from Tec Star

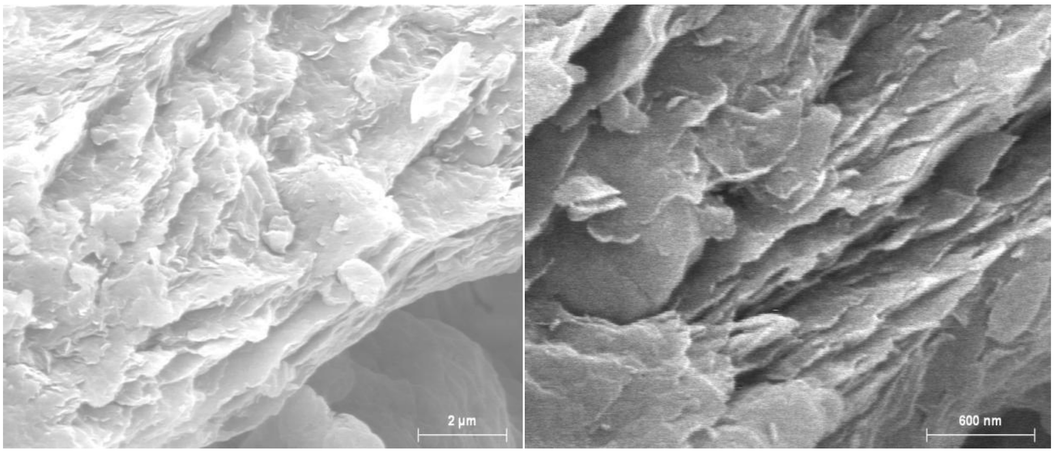


Figure 6. Representative SEM picture of Nanoclays synthetized by ITENE

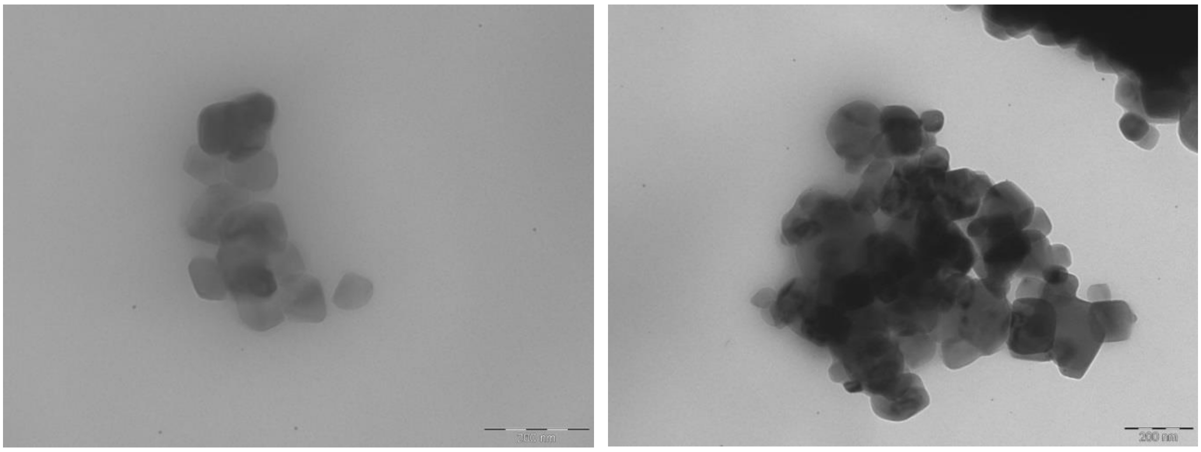


Figure 7. Calcium Carbonate Nanofillers from Tec Star

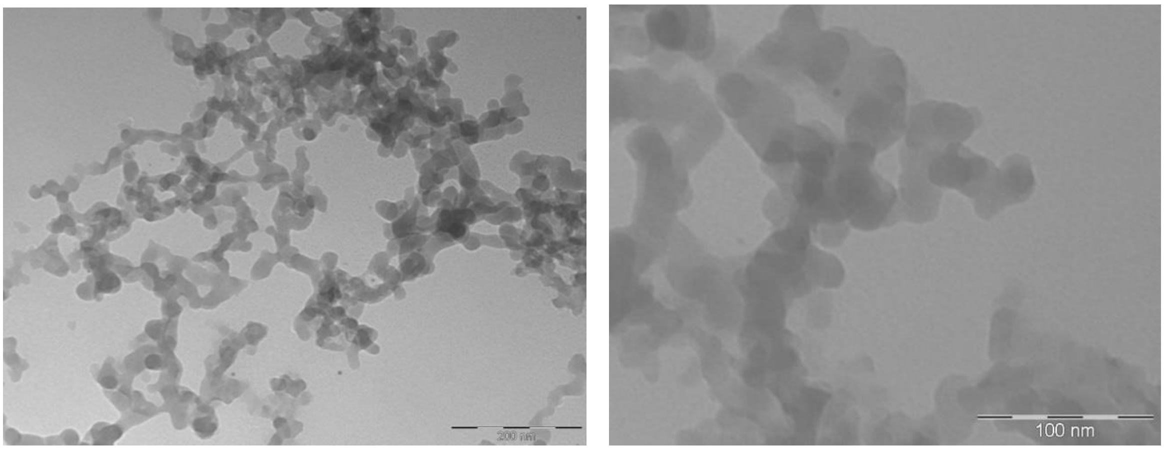


Figure 8 . SiO_2 Nanofillers from Tec Star

3.3.3. Hazard Evaluation   (WP2)

- **Experimental Set Up for Ecotoxicity Studies**

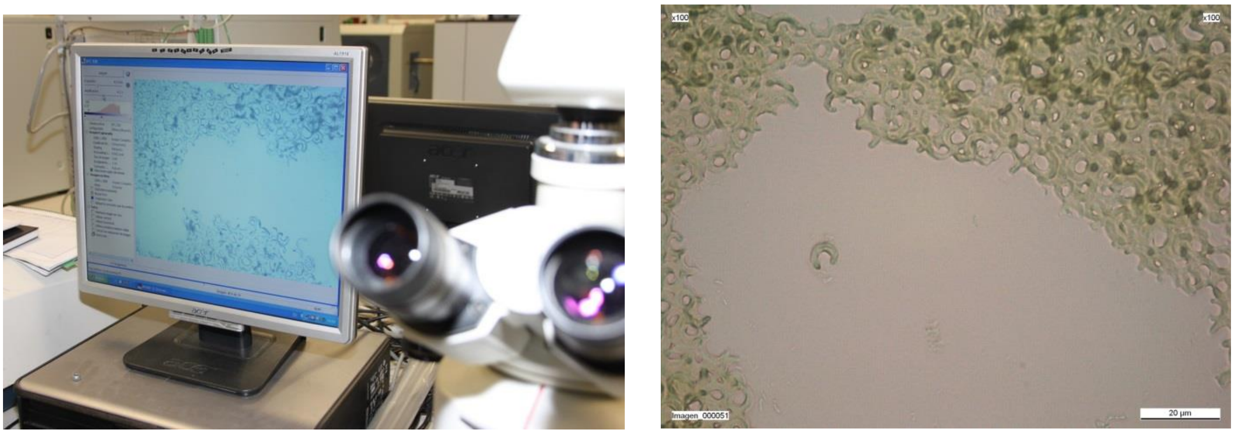


Figure 9. Sample of the freshwater alga *Pseudokirchneriella subcapitata* used for ecotoxicity testing

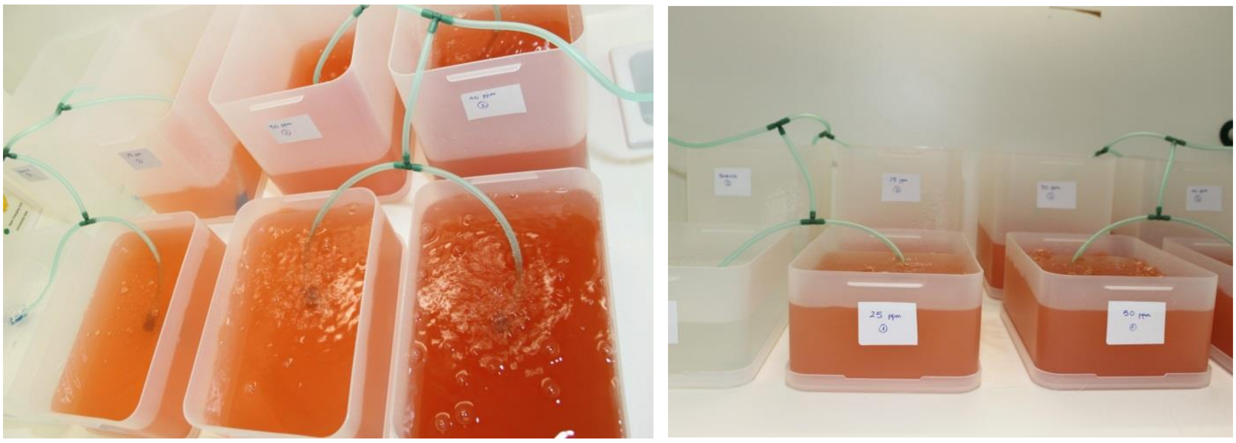


Figure 10. Picture of the micro-mesocosm study reproducing the environmental conditions of a fresh water ecosystem

- **Experimental Set for toxicological studies**

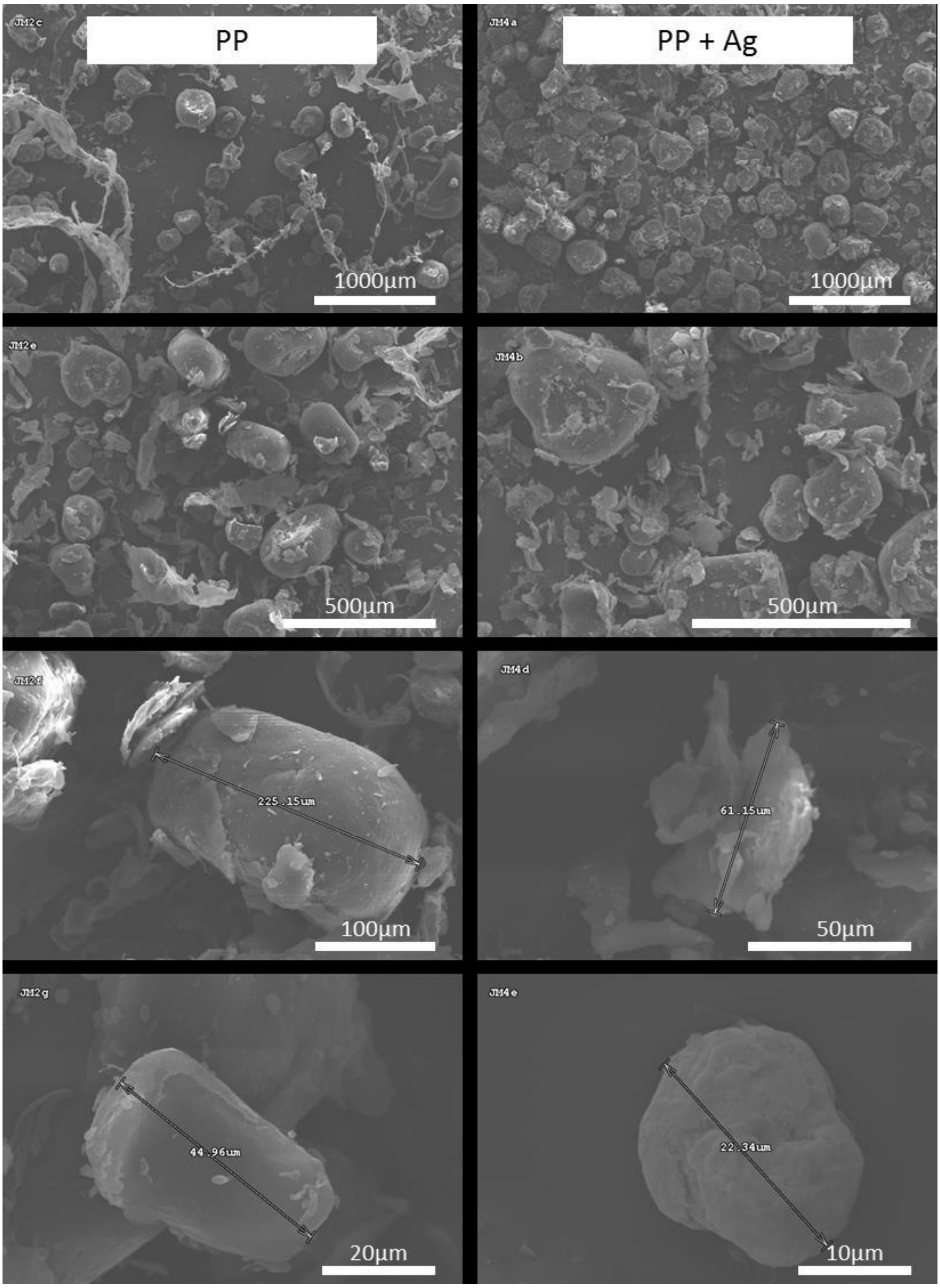


Figure 11. SEM images of micronised polymers and nano-composites as dry powders. Taped samples collected following final micronisation step (jet-milling).

3.3.4. Exposure Assessment and RMMs testing (WP3)

Figure. 12. Evaluation of the exposure to the target nanofillers in real exposure conditions

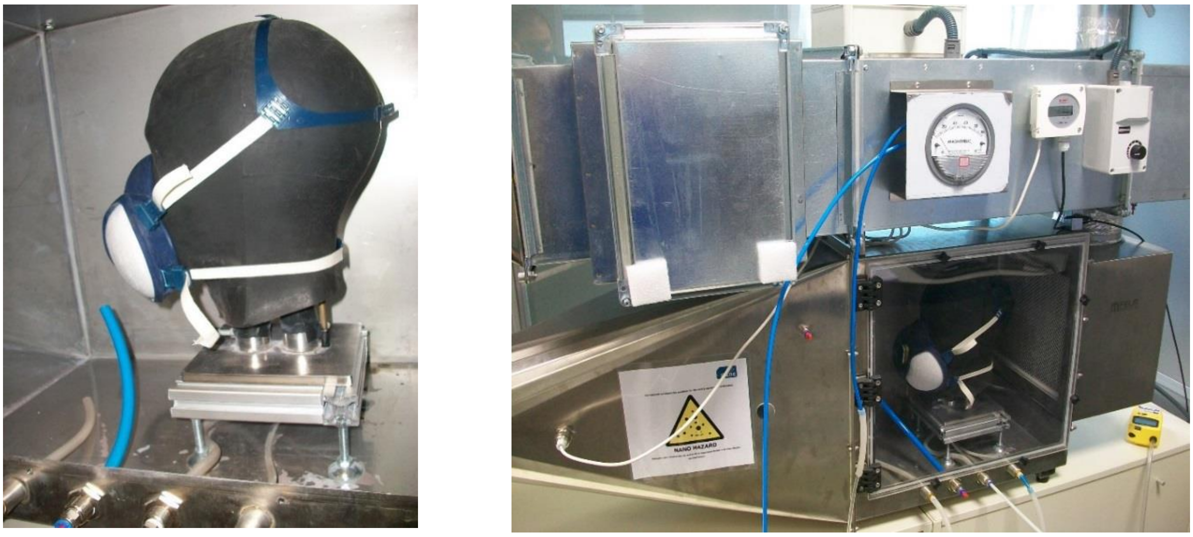


Figure 13a.Sheffield head detail, and Sheffield head perform – RMM testing

Figure 13b.Illustration s from the guide related to the use of RMM – RMM testing

4. Dissemination Activities

4.1. Project Logo

Figure 14. NanoSafePack Logo

4.2. Participation in networking events

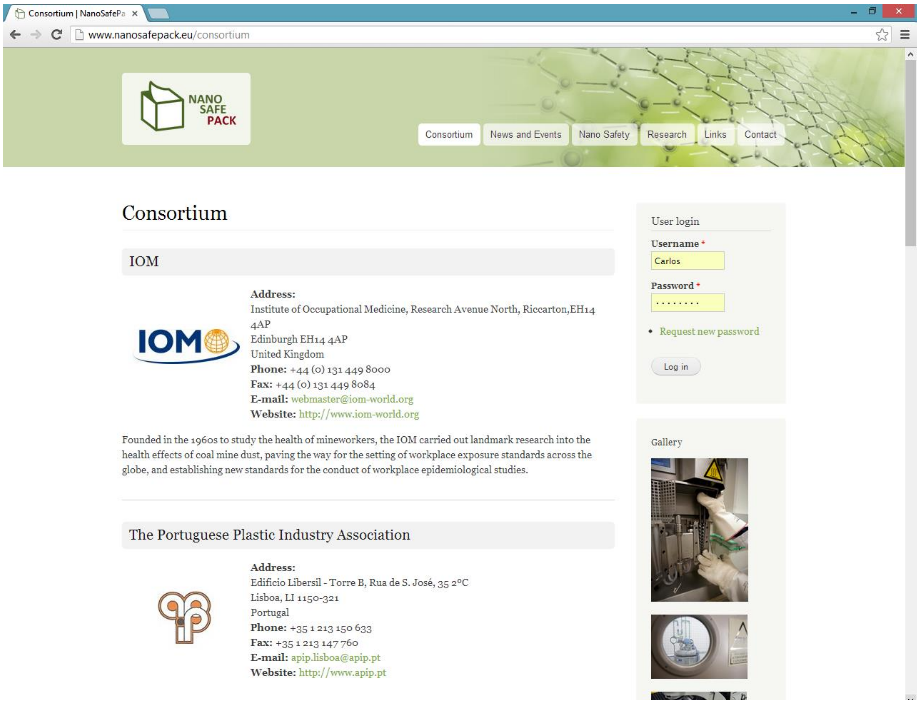
Figure 15. Presentation of the project during the NanoSafety Cluster meeting hold in Grenoble from the 29th to 31st of May 2012.

Figure 16. Presentations by Carlos Fito as technical coordinator and Eva Araque as researcher during the Workshop in Equiplast Trade show held on the 2-3 October, 2014, in Barcelona.

Figure 17. Training workshop held on the 19th of Novemeber, 2014, in the Facilities of EuPC in Brussels.

4.3. Other Dissemination Materials

- **Project Web Site – www.nanosafepack.eu**



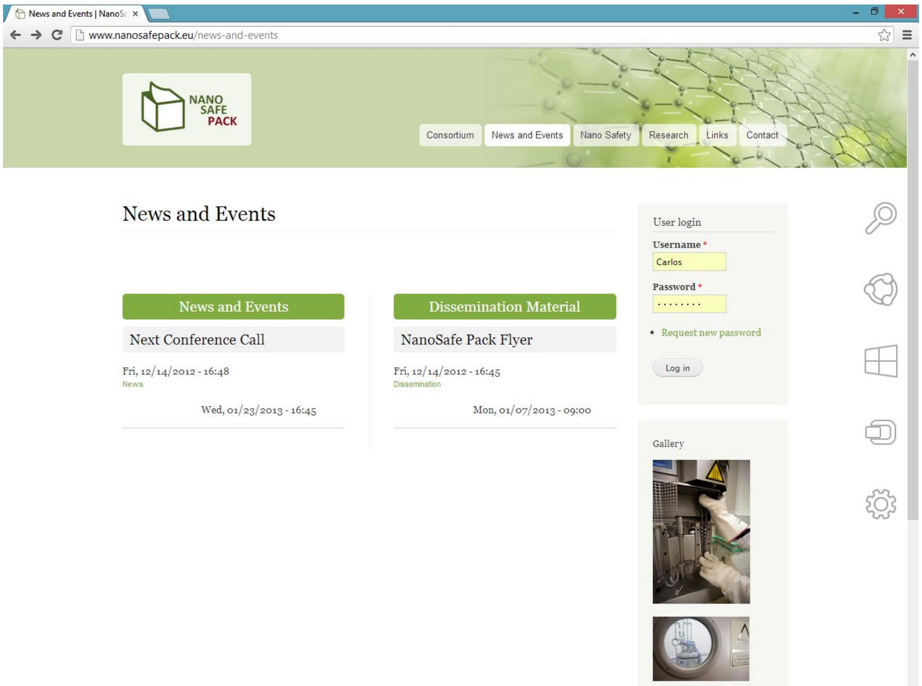


Figure 18. NanoSafePack WebSite screenshot

- **Project Brochure**

Figure 19. Extract of the Project Brochure

- **Cover of the Best Practices Guide**

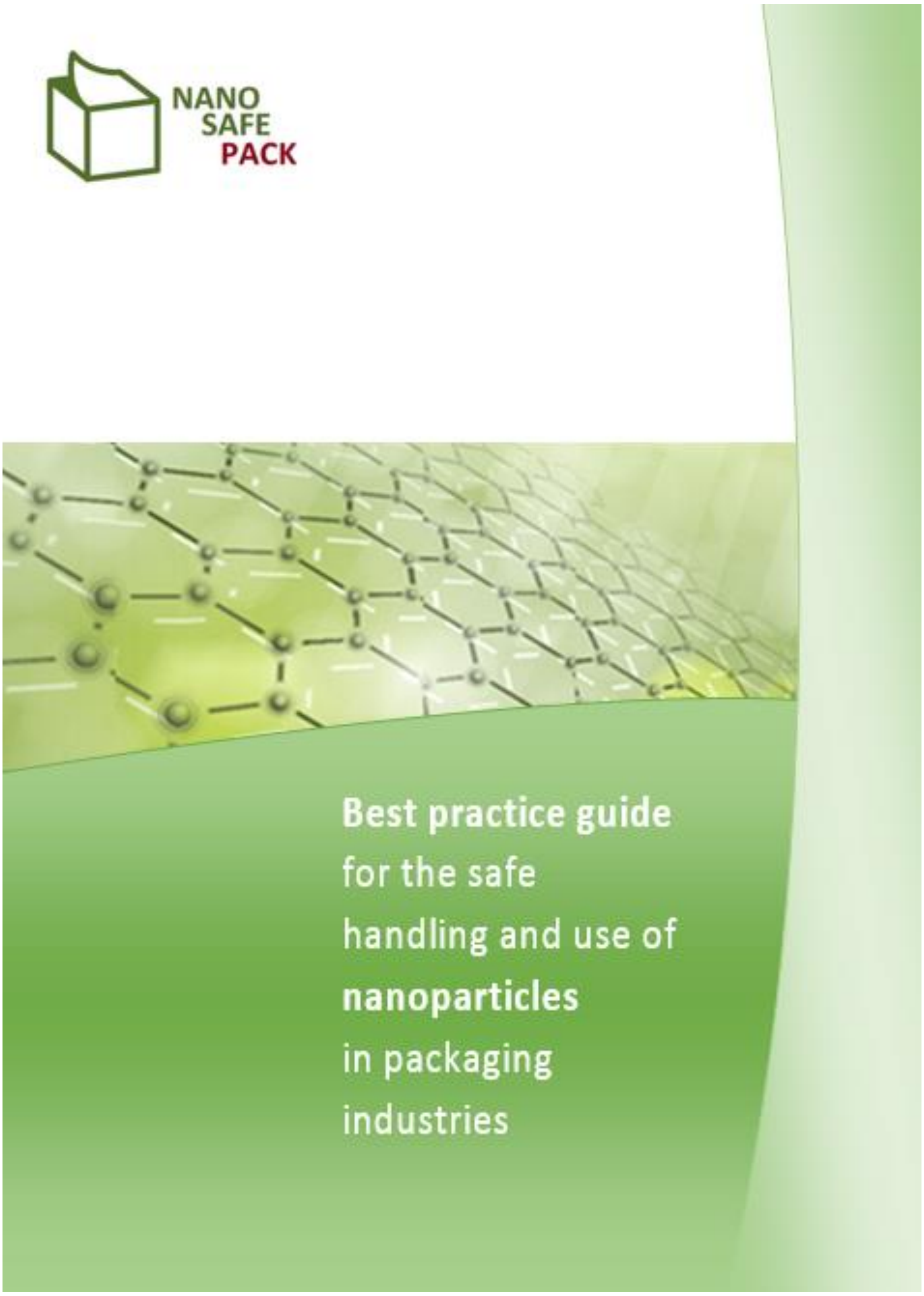


Figure 20. Cover of the best practices guide

- **USB card developed to commercialize the best practices guide**

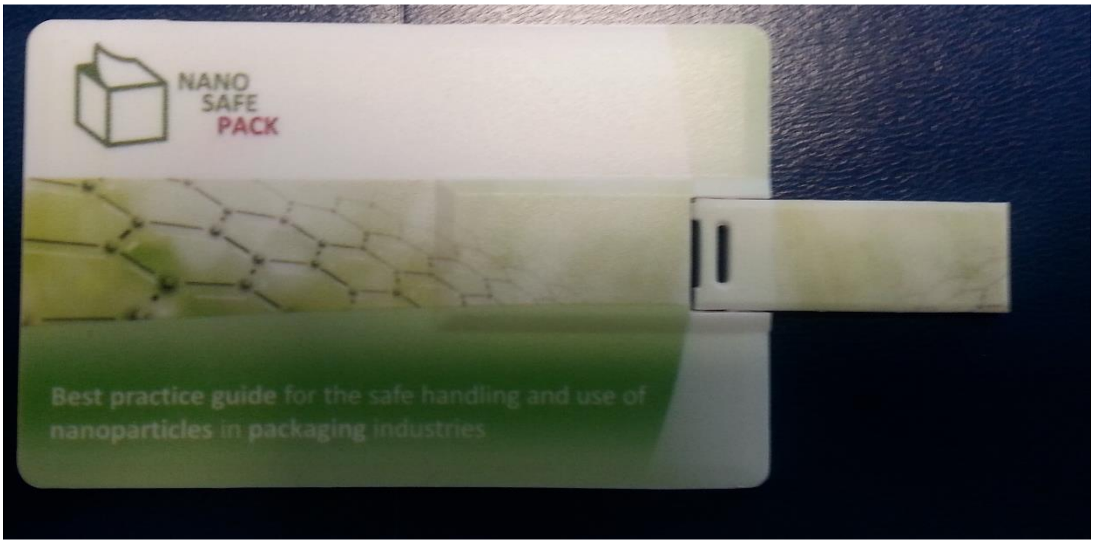


Figure 21. USB encrypted card developed – pdf version

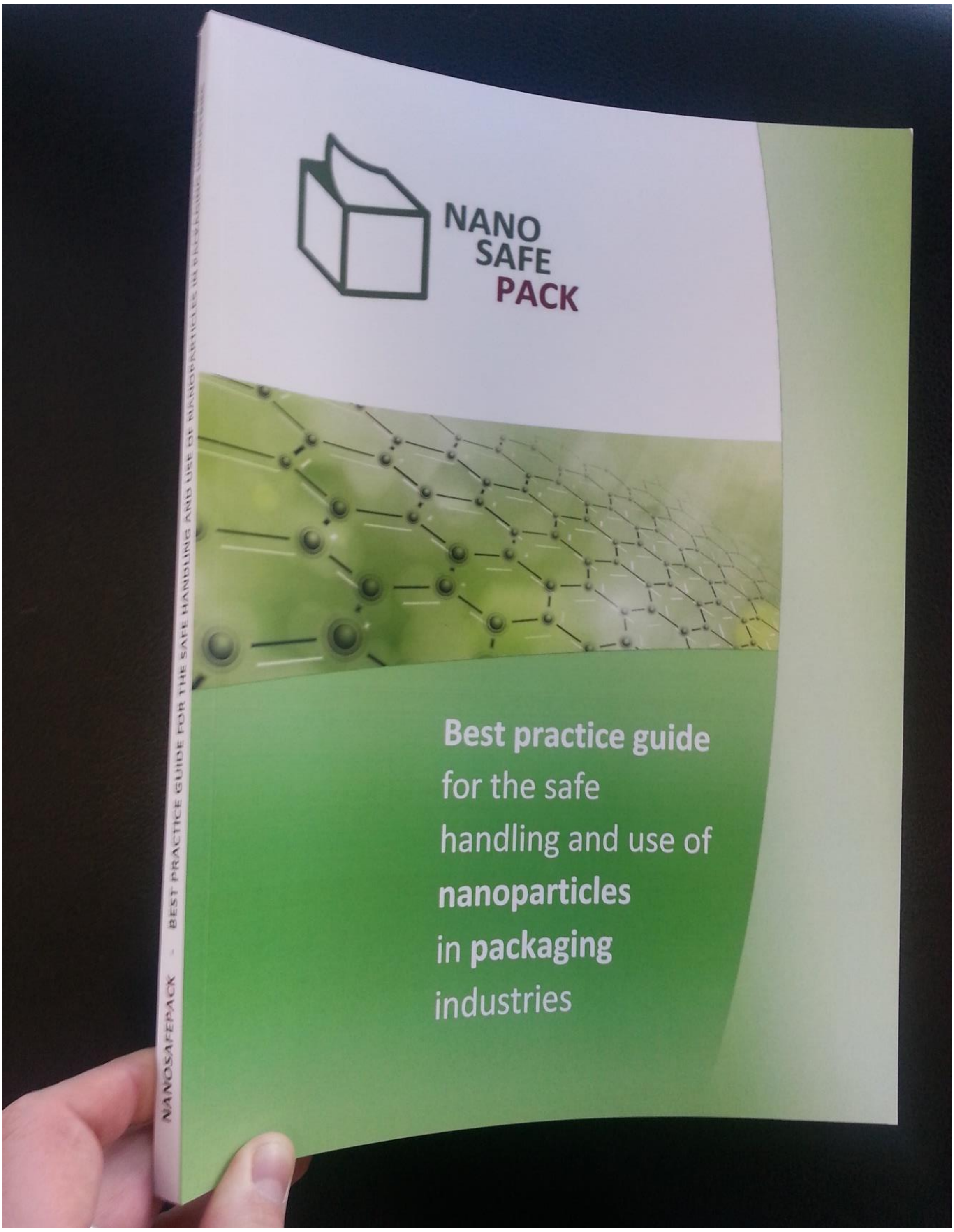


Figure 22. Hard Copy– printed version