

## **Executive summary:**

### **An executive summary**

The main results of the project cover developing innovative concepts and reliable methods for characterizing ENP in workplace air with novel, portable and easy-to-use devices suitable for workplaces.

Identification of relevant physico-chemical properties and metrics of airborne ENP was achieved through designing and building a nano-metal oxide reactor together with engineered nanoparticle (ENP) aerosol synthesis reactors. The materials were produced and characterized. A list of 23 reference materials for the project's needs was established.

The association between physico-chemical and toxicological properties of ENP was successfully identified and the knowledge on the ENP's biological behaviour and the biologic responses was increased.

Analyzing industrial processes as a source of ENP in workplace air was performed using the exposure scenarios and sampling strategies that were generated during the project.

The device development sub-project progressed during the project life-time excellently and exceeded the high expectations. In the outset, seven pre-prototype devices and measurement instruments were planned to be developed in the project, but in the end, the result was that 17 new pre-prototype devices and measurement instruments in four different device families were developed and also tested in the field.

These four device families are:

- 1) total or size specific N-S-M concentration in real time;
- 2) material specific monitors in real-time or quasi-real-time;
- 3) samplers for off-line particle analysis; and
- 4) pre-separator modules for size fractions relevant to the human respiratory tract.

Developing methods for calibration resulted to the calibration tool 'CAIMAN', which was used by the device developers extensively. Testing of the novel devices in real and simulated exposure situations was performed in Nanotest facilities in Round robin tests in real conditions.

The dissemination activities of the research results to promote the safe use of ENP were carried out through guidance using educational materials (brochures, posters, and workshop). Surveying and developing standards in the field of nanosafety at the European level enhanced the implementing of safety objectives in ENP production and handling. Promotion of safety-related collaborations through an international nanosafety forum of experts from interdisciplinary fields and five continents was fruitful for networking and knowledge transfer. The International Congress on Safety of Engineered Nanomaterials and Nanotechnologies, SENN2012 gathered 226 participants from 26 countries during Oct. 28-31st in Helsinki to discuss the next steps in developing the field of nanosafety. The distribution of the results of the project will be assured through the Handbook on Safety of Engineered Nanomaterials to be published by Elsevier in 2013.

These outcomes of the project will also promote safe use of ENP, and promote their safe production, and thereby increase the competitiveness

of nanotechnologies through emphasizing safety aspects in all areas of nanotechnology applications. The potential of the project to produce beneficial social and socio-economical results is also remarkable. The ultimate goal of the project is to promote a positive impact on safe handling of engineered nanomaterials and safety of nanotechnologies in European Union and beyond. One important means through which these goals have been achieved has been the reduction of uncertainties related to nanosafety, and the promotion of safety thinking among key stakeholders in the field. All these actions will promote the competitiveness of the European nanotechnology industry. The European Commission celebrated the project as one of its success stories on May 20th, 2013 and at the Industrial Technology Best Project Awards 2012 in Aarhus, Denmark, the project was one of the 10 finalists out of 63 projects and received an award. An indication of the impact of the project is a new NANODEVICE spin-off project NanoSTAIR CSA activity that started in September 2012, and that promotes standardization activities related to nanosafety.

## **Project context and objectives:**

### **Summary of project context**

Engineered nanoparticles (ENP), defined as having at least one dimension  $\geq 100$  nm, have attracted a great deal of interest during recent years, due to their many technologically interesting properties. The unique properties of ENP and their applications have given birth to immense technological and economic expectations for industries using ENP. However, some of these properties have given rise to concern that they may be harmful to humans. This has prompted scientists, regulators, and the industrial representatives to investigate the features of ENP in order to be sure of their safe use in nanotechnologies (NT), i.e. technologies utilizing ENP. The European Commission has also explored in-depth the characteristics of ENP and issued a document on ways to assure the safety of ENP.

ENP cannot be considered as a uniform group of substances. They are produced from many substances, in many forms and sizes and with a variety of surface coatings. The health assessment of such diverse materials requires validated analytical methods both for their characterization in bulk samples, and for the detection and measurement of those ENP in workplace air since there they have the greatest potential for human exposure. ENP concentrations and size distributions by number, surface area, and mass, ENP composition and reactivity, ENP shape crystallinity, porosity, solubility, and ENP bio-persistence constitute the parameter set which must be assessed first in order to evaluate the exposure to, and the toxicological effects of these new materials.

Several types of ENP including titanium dioxide and carbon nanotubes (CNT) are known to produce pulmonary inflammation and fibrosis in animals. Oberdörster et al. have shown that manganese oxide ENP can reach the olfactory bulb in the forebrain of experimental animals via transport along the olfactory nerves which innervate the epithelium in the nose. In addition, recent observations indicate that CNT may gain access also to other organs via the airways, e.g. to induce inflammation of the vasculature. Unfortunately, there are no inexpensive, field-worthy ways to reliably assess the levels of biologically relevant exposure to ENP in workplaces.

One major uncertainty in the safety assessment of ENP arises from the lack of knowledge of their physico-chemical properties and behaviour in the airborne state. Nano-sized titanium dioxide particles form agglomerates, and CNT create bundles and ropes. The tendency of airborne particles to agglomerate is of special importance for ENP because they may very rapidly change their specific size-related properties or become attached to a background aerosol. Separation and identification of ENP against the ubiquitous background aerosol originating from different sources is another special and difficult challenge facing ENP monitoring in the workplace.

The thorough characterisation of airborne ENP is complicated by: the dynamic behaviour of ENP in workplace air, the large parameter set required for their complete characterization, the range of ENP materials already in use, and a the multitude of biological responses. At present, there is no appropriate set of devices which could be used for monitoring, measuring and characterizing ENP in workplace environments.

Measurement and monitoring of ENP which are present in the air in workers' breathing zones in this proposal means capturing all relevant information about the amount (number, surface area or mass concentration) and size distribution, as well as shape, composition and chemical reactivity of airborne ENP in a given size class or a broad size range.. Selection of the most relevant metric(s) for health-related sampling of ENP is an important component in the development of the concepts, methods and technology for ENP monitoring at workplaces. For this purpose, simultaneous toxicological characterization of ENP will also be carried out because this information is needed for the assessment of the many parameters which can be measured. In addition, there is a need to characterize the ENP emitted from processes and to obtain data on true exposure levels of ENP in workplaces in order to define the performance requirements of the exposure assessment means.

The real challenge ahead for ENP monitoring and health risk assessment is to

- (a) redesign 'ENP-capable' instruments already in laboratory use into portable and affordable devices,
- (b) to expand the sensing technology available for ENP detection by adopting new options with realistic potential for real-time measurement and compact design; and
- (c) to extend the metrics into new areas such as CNT shape identification and catalytic properties. Section 1.3 of this proposal has been structured according to these objectives.

Each of the above avenues addresses an important demand:

- (i) making current technology more compact, more affordable and more versatile will provide imminent short-term solutions required by toxicologists and the inhalation exposure community;
- (ii) new sensing technology will have a mid-term effect by providing sophisticated measurement options for very small particles which can be adapted to the needs of aerosol monitoring technology. Finally,
- (iii) the development of methods and pre-prototype devices capable of capturing entirely new metrics will provide new tools to characterize airborne ENP. In each category, the focus is on real-time, on-line methods and devices.

### **Progress beyond the state of the art**

At the time of planning the project, there were no portable and easy-to-use measurement devices for the characterization and assessing the levels of ENP in workplaces. There are devices that can be used to measure particle size distribution, nano-sized particle number concentrations, or effective surface area of ENP, but these devices are heavy, laborious to use, very expensive, and there are limitations in their sensitivity. Moreover, many of the devices do not allow on-line measurement of given ENP, an important feature for using of these devices in workplaces for assessing the levels of exposure of workers potentially exposed to ENP's. One of the shortcomings of the current devices, even of the expensive and heavy pieces of equipment, has also been the limitations in terms of the particle parameters. Thus, a major challenge at the current situation is to be able to develop devices which provide solutions to these challenges and that allow inexpensive assessment of exposure of workers to ENP (see Maynard et al., 2006).

The overall goal of the NANODEVICE project is thus to systematically develop a family of devices for direct (in-situ) monitoring and

measurement of a broad range of relevant ENP characteristics in the workplace air with high time resolution (on-line). Based on mutually complementary approaches, these devices will include the measurement of ENP number concentration, active surface area, shape, chemical properties and other parameters. Some devices will cover a particularly wide particle size range since this is needed for workplace surveys, while others will allow the size-selective on-line determination of number to surface area ratios for dose assessments. Other devices will enhance the detection sensitivity for mass or number for extremely fine particles, and others will permit direct monitoring of nanofibres or catalytically active materials, either attached or unattached. The overall approach also includes concurrent partial off-line characterization of ENP for additional studies. Never before has there been such a concerted and strategic effort expended for the development of devices which focus on ENP aerosol monitoring and measurement needs in the workplace.

The technical device development effort is supported by

- (i) a centralized production of some of the test ENP to be used in testing of different devices for the evaluation of levels of these ENP in the air;
- (ii) comparative testing, calibration and validation of the devices under defined conditions. This will ensure that for the first time there will be uniform test standards, and a reliable performance assessment of the devices against the characteristics for which they have been designed. The technical device development effort will be further complemented by
- (iii) an evaluation of the biological and toxicological effects associated with the different physico-chemical and surface properties of the chosen ENP through simple and well characterized in vitro toxicological cell systems and carefully chosen endpoints, and an assessment of the most suitable metrics of ENP which to be targeted by the novel detecting devices.

By making available this information about the association of different ENP properties with their biological effects available to device developers at a relatively early stage is a novel concept in technology transfer. This added information will allow them to evaluate associations that could not have been taken into consideration previously when they were developing prototypes simply in their own commercial Research and Development (R & D) units.

The applicants envisage that the strategy adopted in this proposal will become a benchmark for future undertakings aimed at developing novel methods for the same purposes. In particular, the systematic refinement and adaptation of device inter-comparison strategies and the development of identical calibration aerosols for the envisaged broad range of measurement devices will become a reference point for the future. The features and challenges described above in this chapter can be used to quantitatively assess the success of the project in achieving its goals.

The NANODEVICE Consortium has also designed a uniquely effective dissemination and implementation plan to ensure the results of the project are widely publicized. One essential feature is the capacity building and strengthening of the NANODEVICE Consortium through promoting human mobility via an extensive visiting programme for participating junior and senior scientists. This approach also includes the generation of a wide variety of teaching methods with presentations and workshop formats intended for different audiences, support for the Commission by generating a state-of-the-art nanosafety handbook to be used by

regulators, experts in the field, companies and the scientific community emphasizing the results of the NANODEVICE project but building on existing knowledge on the safety of ENP and NT. These dissemination goals will be further promoted by establishing a global Annual Forum for Nanosafety with experts on nanosafety issues and nanotechnology invited from different parts of the world representing different groups including scientists, experts from industry, regulators, and policy makers, and with a strong emphasis on the promotion of standardized procedures to allow the industry, regulators and the scientific community to more effectively and reliably use the more comparable results based on the standards which guarantee the safety of ENP and NT. At the conclusion of the NANODEVICE project, an International Congress on Safety of Engineered Nanoparticles and Nanotechnologies will be organized with world leaders as speakers.

This Congress will be the major promotional event of the project signalling its completion in 2012. It will aim to maximize the favourable effects of the project not only on measurement of airborne ENP, but also on promotion of the safety of ENP and NT in the European Union and globally. There are no doubts that this project will represent a quantum leap in improving the capabilities to measure ENP and more generally to better workplace safety in ENP production and use and NT in general. The goals presented in the chapter above can be used to quantitatively assess the progress of the project to reach its goals and general objectives and to gain the impact of the work carried out within the frame of the project to increase the safety of nanotechnologies, to provide policy and regulatory support to the Commission as well as to evaluate the overall impact of the project on the society.

Overall objectives of the research: New and innovative concepts and methods for measuring and characterizing airborne ENP with novel portable and easy-to-use device(s) for workplaces; specific objectives of the research project:

1. To identify relevant physical and chemical properties for specific measurement of engineered airborne ENP, and to develop reference materials for ENP aerosols. This objective is related to SP1, WP1, and the work will be on-going during the duration of the whole project, but first deliverables, i.e. ENP reactors and first synthesized ENPs by the end of the first year of the project. Further details are given in the work package descriptions.
2. To investigate the relationships between physical and chemical properties of ENP and their potential toxicity or bioactivity. These objectives are related to the SP2, WPs 2, 3, and 4. WP 2 will continue for the whole duration of the project due to EM characterization of the ENP, whereas WP3 will be ready with non-imaging characterization of the chosen ENP by the end of month 36 since the beginning of the project. WP4 will be finalized by the end of the month 39 after the beginning of the product meaning that all studies aimed at toxicological characterization of the particles will be ready.
3. To analyze the ENP emitted from industrial processes during the production and handling of ENP and to assess levels of ENP in workplaces in order to define performance requirements. Studies in SP3, WP5, will continue for the whole duration of the project but it will provide results on both exposure levels in workplaces and analyses of potential releases of ENP in different industrial processes after the first year of the project (month 12). Furthermore, WP5 will collaborate with other EU-

funded projects, e.g. NANOSH, and obtain exposure data for device optimization during the first and second year of the project.

4. To develop technologies that enable utilization of new concepts in miniaturized and field-worthy specific monitors for ENP. Most of the WPs (WP6-WP12) in SP4 continue for the whole duration of the project, and provide the main deliverables, i.e. pre-prototypes of different nanomonitors at the end of the project. Exceptions are WPs 11 and 12 which will deliver the pre-prototypes already by the end of the month 36 and 30, respectively. The development of these pre-prototypes will take remarkable amount of time as they need to be tested in the SP constituting of WP 13 and 14.

5. To develop methods for calibration and testing of the newly developed concepts and methods and devices in simulated and real life exposure settings. The studies in the SP 5 including WPs 13 and 14 will continue for the whole duration of the project. This is due to the need to develop adequate calibration conditions in collaboration with WPs 1 and 5 and then carry out the calibrations of the devices until the end of the project excluding two exceptions (WPs 11 and 2) that will provide deliverables earlier.

6. To effectively disseminate the results of the research, to promote the safety of ENP by guidance and standard development, to provide training and guidelines education, so that ENP can be safely produced and handled, and by promoting collaboration of all those concerned with the safety aspects of ENP. The dissemination and exploitation SP consists of WPs 15-21.

The main goal of these WPs is to assure that the impact of the project on the society can be assured. Support for standardization is a relatively short WP that aims at supporting the ISO and comparable processes dealing with ENP. The rest of the WPs in this SP will end at the end of the project providing educational material during the duration of the project after the end of the first year, and training will be carried on from the beginning of the second year onwards. Annual Forum for Nanosafety will have one annual meeting starting during the second year, but contacts to the key-players to be invited to the Forum will take place during the first year of the project. International Congress Safety of Engineered Nanoparticles and Nanotechnologies will be organized at the end of the project, but its organization will continue during the whole duration of the project. Nanosafety handbook will appear at the end of the project, but the planning and writing process will start as soon as the project starts. This WP will produce frequent progress reports as all of the WPs will produce. The human mobility program has been planned to start during the second year of the project, and the deliverable are the number and duration of the visits by scientists to different partner laboratories, or other laboratories.

## **Project results:**

### **A description of the main Science and Technology (S&T) results/foregrounds (not exceeding 25 pages)**

#### **WP1 Physicochemical characterization of reference materials and production of tailored ENP aerosols as well as purchasing and characterization of commercially available nanomaterials**

During the first reporting period AALTO has characterised iron catalysts particles from hot wire generator (HWG) and preliminary tests have been performed of SWCNT synthesis with the concept reactor. TUT has been building up the portable metal oxide particle generator, carrying out test measurements with TiO<sub>2</sub> and SiO<sub>2</sub>. Also, negotiations with Partner 23 on participating in the coming experiments in Bochum, July 2010 have been performed. UEF has been building up of metal nanoparticle reactors (CVS, FSP) and running test measurements of CVS and FSP reactors with iron, silicon composite and lithium titanium oxide.

During the second reporting period Deliverable D1.1 'Nanocarbon, metal and metal oxide ENP aerosol synthesis reactions are operational' was achieved. Partner 2, AALTO has designed, built and used a SWCNT floating catalyst synthesis reactor based on iron catalyst nanoparticles and carbon monoxide as carbon precursor to generate fresh SWCNT aerosols. SWCNT parameters (tube diameter distribution, bundle diameter, chiral angle distribution) can be controlled. Partner 17, TUT has finalized the metal oxide flame reactor for nanoparticle generation and the system is operational. Analysis of titanium dioxide and magnetic Fe<sub>x</sub>O<sub>y</sub>-particles generated by flame reactor were carried out and the analyses are continuing. Nanopowder collection and further development of collection by ESP (electrostatic precipitator) were carried out and are continuing. TUT Participated in two campaigns in the Nano Test Facility in Dortmund (July 2010 and July 2011) with portable flame reactor and the data analysis of the two campaigns was performed. Nanoparticle measurements at TUT nanoparticle processing site, as a nanoparticle workplace, during summer 2011, were performed for WP14. Partner 19 UEF designed built and tested CVS, FSP metal nanoparticle reactors and produced and characterised iron, silicon composite and lithium titanium oxide nanoparticles. Sampling system has been build up and tested as well as dilution systems (PRD) for fresh aerosol.

During the third reporting period WP1 'Physicochemical characterization of reference materials and production of tailored ENP aerosols as well as purchasing and characterization of commercially available nanomaterials' is led by AALTO. The objective is to develop and study the syntheses of different kinds of ENP aerosols, including carbon nanotubes and nanobuds, metals and metal oxides.

In the reporting period we have achieved deliverable D1.2: Nanocarbon (CNT, CNB), metal and metal oxide ENP materials produced and characterized as well as deliverable D1.3: Report on ENP aerosol generators and all materials.

#### **WP2 Physical and chemical properties by electron microscopy**

During the first reporting period the standard methods for generating, analysing, characterising and reporting the electron microscopy analysis of nano-objects and agglomerates were in preparation. There was also a

delay in the full selection of powders in order to integrate with other nanoprojects. Some initial characterization of titanium dioxide and carbon nanotube materials, selected in the workplan for WP4 toxicological tests were carried out by FIOH. Characterization included FEG-SEM and TEM analysis of the morphology and EDS analysis for the composition.

A final selection of common nanomaterials were selected and sourced and distributed for use by SP2 (WPs 2, 3 and 4) in September 2010. A total 23 different nanopowders were obtained to link and bridge analysis in SP1 and SP2 as well as choosing a wide range of powders with different characteristics and properties for device challenging. During the second reporting period the standard EN15051 rotating drum dustiness tester (and a smaller drum version) was used to produce airborne dispersion of these nanopowders for both WP2 and WP3 analyses to allow direct comparison between different on-line methods with electron microscopy.

The electron microscopy results showed that that most of the nano-objects generated from a powder were agglomerates of primary nano-objects. This suggests that the energy from the dustiness test, which replicates typical handling situations such as pouring and shovelling, has insufficient energy to completely break up the agglomerates into the primary objects; although rapid re-agglomeration could also be taking place.

Typically the mode of the electron microscopy size distributions was between 100 - 500 nm with some nanopowders showing evidence of a second but smaller size mode, usually above 1000 nm. Functionalised calcium carbonate nanopowders gave much higher releases (two orders of magnitude) than the nano-objects from which they are made but the size distribution was similar. The electron microscopy size distributions are being used to compare the performance of several on-line size measurement instruments that were run simultaneously during the dust generation.

During the third reporting period the following results were achieved. Nearly all nanoparticles when generated from a powder are agglomerates of primary particles. The smaller the primary particles the larger the number of primary particle in the agglomerates. Some dusts appear to have a bi-modal distribution with smaller agglomerates below 100 nm giving significant peaks. Functionalised nanoparticle powders can give much higher releases than the un-functionalised particles from which they are made. The difference for calcium carbonate was around two orders of magnitude.

### **WP3 Physical-chemical properties of ENP evaluated by using non-imaging techniques**

During the first reporting period in WP3, there were no significant results obtained as the WP activities have focused in selecting and getting the material and start analysis. WP3 did not have to fulfil any deliverable or milestone in year 1. According to the DOW, there will be one Milestone in the next period and we are on track with analysis of particles in suspension.

During the second reporting period the following parameters were studied: 1. Primary physicochemical characteristics of particles, 2. Particle dustiness, 3. Particle dispersion in liquids, 4 and 5. Hydrochemical reactivity and biodurability.

1. In the physicochemical characteristics X-ray diffraction was used to determine the average crystalline size and the specific surface area was determined by BET method. It was discovered that the particles were larger than the reported by the industry/ vendors. Thermogravimetric analysis (TGA) combined with Gas Chromatography Mass Spectrometry (GC-MS) and/or Liquid Chromatography (LS) MS were important tools for identification of particles with presence of potential surface coatings and their identification. Surprisingly many of the commercial nanoparticles contained surface-coatings or were associated with organic material, even-though it was not reported by the producer/vendor.
2. In the particle dustiness studies 23 nanoparticle powders were tested and a wide range of dustiness from very low to very high was observed. A specific test-campaign was held to perform a multi-instrumental analysis of the surface area of released respirable dust as compared to the specific surface area of test powders. Analyses are now being completed to determine whether there is a link between physicochemical characteristics and dustiness levels of the tested powders. Preliminary results suggest that the specific surface area of powders in general may be used to calculate the surface area of respirable dust.
3. In the particle dispersion studies, particles are dispersed into cell-medium cRPMI (1 mg/ml) in a 37 kHz ultrasound bath for 20 minutes following the test item preparation protocol used by WP4 . It was found that the procedure can be used to disperse oxides and poorly agglomerated particles, but the method is less capable for dispersing entangled carbon nanotubes and not suitable for dispersion of hydrophobic materials. Detailed analysis of dynamic light-scattering and disc-centrifuge data is on-going to quantify the size-distributions in the dispersions.
- 4 and 5. In the hydrochemical reactivity and biodurability tests a method using an atmosphere-temperature-pH controlled stirred batch reactor has been developed for test of particle dissolution, acidity and redox activity of nanoparticles dispersed in surrogate biological fluids and cell mediums under highly controlled conditions. Proof of concept has been made and the system awaits final modification for optimal control of test atmospheres. An alternative and faster procedure is being established using incubation plates with build-in on-line pH and O<sub>2</sub> sensors as a screening method. The system still awaits delivery.

During the third reporting period the following parameters were studied:

1. Primary characteristics of particles,
2. Particle dustiness,
3. Particle dispersion in liquids,
4. Hydrochemical reactivity and
5. ENP biodurability.

#### 1 Primary physicochemical characteristic:

Continuation of the materials- and data analysis from period 2, showed that the specific surface area determined by the BET method did not always indicate the existence of a nanoparticulate powder when particles were partially aggregated, nanostructured or coated. This was highly significant for some carbon nanotubes and Ag nanoparticles with original stabilizers or direct surface-coating. This has implications for the methods available for identifying particulate nanomaterials.

2. Particle Dustiness: Additional tests increased the dustiness tests to comprise a total of 23 powders. The powders were shown to have a wide range in dustiness ranging (very low to high). High similarity was found for respirable dust tested using both the standard EN15051 and the downscaled NRCWE rotating drum. The INRS Vortex shaker generates

different dustiness levels and characteristics. No immediate link was observed between primary physicochemical characteristics and dustiness level. Preliminary results suggests that the specific surface area of powders may be used to estimate the surface area of respirable dust based on the mass of respirable dust times the specific surface area, but deviations may occur. For an embedded instrument challenge study between dust surface area measurements using on-line diffusion charge surface area monitors and FMPS surface areas converted from particle-size-distribution analysis. Two surface area monitors showed modest to poor comparability and material dependent linear to non-linear relationships were found between the surface area monitor data and dust surface area recalculated from size-distribution analysis.

3. Particle dispersion in liquids: From continuation of period 2, quantitative analysis of dispersions was completed. We conclude that only 2-3 nanomaterials were well-dispersed in the cRPMI and DMEM+FBS. There was generally good correlation between the size-distributions obtained in cRPMI and DMEM+FBS at higher doses (0.3 mg/ml), but poor at low concentrations (0.03 mg/ml). Interestingly, there was generally poor correlation between primary hydrodynamic size-modes achieved by DLS and DCS. This is partly due to the methodological differences. DLS data may be affected by use of different optical data on the test materials. However, for proper comparison of sizing true viscosities in specific dispersion are needed.

4 and 5 Hydrochemical reactivity and biodurability: The 24 well sensor dish reader (SDR) system with online monitoring of pH (5-7) and O<sub>2</sub> (0 to 262.7  $\mu$ mol/L) concentration was evaluated and selected for testing the solubility (biodurability) and reactivity of nanoparticles dispersed in surrogate lung lining fluids and cell mediums. Dissolution was only detected for in ZnO and two CaCO<sub>3</sub> samples tested, which also induced pH changes, whereas clear O<sub>2</sub> reactivity was found for nanographite, MWCNT, and mixed Fe-oxides. The results should be used with the aim to improve our understanding of toxicological mechanisms as well as setting directions for future development of devices incorporating biologically relevant metrics.

#### **WP4 Toxicological properties of ENPs**

During the first reporting period for toxicological analyses tests were performed on: the immunotoxic effects, cell viability, cytotoxicity and DNA strand breaks. The expression of cytokines and chemokines was assessed in mouse macrophages to study the immunotoxic effects of exposure to selected nanomaterials. Cell viability was assessed by counting the proportion of dead cells in treated cultures versus control cultures using Trypan blue dye exclusion or LDH assay. The genotoxicity of selected nanomaterials was assessed in human bronchial epithelial BEAS 2B cells in vitro. The doses tested were chosen on the basis of two cytotoxicity tests - cell count in using Trypan blue dye exclusion and a luminescent assay detecting ATP. The comet assay was applied to measure DNA strand breaks produced by the nanomaterial exposure.

Based on the studies performed during the first period, following conclusions were made:

1. Immunotoxicology: Some nanomaterials induced pro-inflammatory effects by secretion of essential cytokines and chemokines in mouse macrophages. However, these effects seemed to be material-specific.

2. Cytotoxicity: The cell viability test showed that each nanomaterial studied induced cell death at high concentrations but no drastic effects were seen in the assays. All nanomaterials examined decreased the number of cells in cultures of BEAS 2B cells in a dose-dependent fashion, showing a cytotoxic effect.

3. Genotoxicology: Preliminary results on the genotoxicity studies thus far performed indicated that TiO<sub>2</sub> (mix) induces a dose-dependent increase in DNA damage. TiO<sub>2</sub> (alumina) also produced a significant increase in DNA breaks, but no dose dependency was detected.

During the second reporting period the assessment of the toxicological properties of ENPs was continued and the ENP selection for the toxicological testing was finished. In the immunotoxicological analysis of ENPs cell death and production of pro-inflammatory cytokines were studied using human alveolar epithelial cells, skin cells and primary macrophages; oxidative stress analysis was performed with human alveolar and skin cells. The genotoxicity studies of selected ENPs included studies of cell death and their ability to induce DNA damage and micronuclei (NM) in human bronchial epithelial cells. Also, the template for the data bank of toxicological effects of ENPs was established.

Based on the studies performed during the second period, following conclusions were made:

1. Most of the ENPs studied do not cause cell death or oxidative stress or induce the secretion of pro-inflammatory cytokines in vitro. Only SiO<sub>x</sub> was able to cause cell death in all cell types studied, and it also induces low levels of oxidative stress in the alveolar epithelial and skin cells.
2. Studying the secretion of IL-1 family cytokines utilizing LPS-priming of macrophages seems suitable for the recognition of clearly pro-inflammatory ENPs.
3. Most of the studied ENPs induce DNA damage but do not NM in human bronchial epithelial cells.

The last period of project was used to finish the analysis of toxicological properties of ENPs. Human primary macrophages, THP-1 cell line, human alveolar epithelial cells and skin cells were used in the immunotoxicity testing. Different ENP groups clustered according their chemical properties and their ability to induce responses in different cell types were compared using different tools of statistical analysis. Also, the correlation between ENP's catalytic activity and their ability to induce ROS production was investigated in co-operation with WP11. The genotoxicity studies with selected ENPs were finished according to the DoW. The data bank of toxicological characterization of ENPs was finalized and summary sheets of toxicity are published in the <http://www.nano-device.eu>.

Based on the studies performed during the last period, following conclusions were made:

1. There are similar cellular effects on cytokine response between nanoparticle types in different cell types.
2. There is a strong correlation between the catalytic activity of Pd nanoparticles (generated by WP11) with their ability to induce intracellular ROS production.
3. From the 14 materials studied, metal nanoparticles (TiO<sub>2</sub>, SiO<sub>x</sub>) induce the highest level of DNA damage after 24 h exposure indicating possible genotoxic effects. Still, all materials studied failed to induce NM in human bronchial epithelial cells.

**WP5 Industrial processes, leaks of ENP, burden at workplaces, and levels and size distribution of ENP for requirements of the concepts, methods and pre-prototype devices**

During the first reporting period the following tasks were targeted:

Task 1. Development of a conceptual model of exposure to (engineered) nanoparticles.

Result: Development of a conceptual model for inhalation exposure to ENP  
Task 2. Inventory of expected specifications and requirements/desirables of WP 6-8 devices.

Result: A survey was sent to WP6-8 leaders to achieve 'Requirements for the newly developed devices'. The questionnaire was summarized and documented.

Task 3. Description/evaluation of existing and future (if possible) workplace exposure scenarios with emphasis on exposure conditions, concurrent exposures etc.

Result: A preliminary analysis was made using data from the project 'NANOSH'

Task 4. Identification and filling of knowledge gaps by limited and small-scale experiments.

Result: During the 2nd WP meeting (November 2009, Hoofddorp, NL) knowledge gaps were identified, with focus on the conceptual model. It was concluded that the input value of parameters for (both mathematical and CFD) modelling should be as realistic as possible. Consequently, it was concluded that more data were needed with respect to 'background' aerosols, e.g. ranges of size distributions, particle number concentrations etc. An (overarching) outline of the experimental studies was drafted and agreed (M5.2). During the 3rd WP meeting (April 2010, Nancy) further details were discussed. Actual (experimental) experiments will be in close collaboration with WP1 (particle generation) and have been scheduled for August 2010.

During the second reporting period the following tasks were done:

Task 1. Development of a conceptual model of exposure to (engineered) nanoparticles.

Result: Publication of a conceptual model for inhalation exposure to ENP  
Task 2. Inventory of expected specifications and requirements/desirables of WP 6-8 devices.

Result: A survey was sent to WP6-8 leaders to achieve 'Requirements for the newly developed devices'. The questionnaire was summarized and documented.

3. Identification and filling of knowledge gaps by limited and small-scale experiments.

Result: An overview of measured and expected concentrations for various exposure scenarios was reported.

4. The description/evaluation of existing and future (if possible) workplace exposure scenarios with emphasis on exposure conditions, concurrent exposures etc. is in progress. During the fall of 2010, actual experiments (measurements) have been conducted in close collaboration with WP1. The dimensions and experimental set-up have been used for meshing the geometry to run CFD modelling. The first preliminary conclusions based on experiments and modelling confirm that coagulation is only relevant at high concentration, obstacles in the room do not

relay affect these processes, and the effect of ventilation clearly can be observed. Currently, the first draft report on the experimental study is under review, whereas the CFD modelling will run again including real workplace data for background aerosol simulations.

During the third reporting period the following task was achieved: Identification and filling of knowledge gaps by limited and small-scale experiments. An (overarching) outline of the experimental studies was drafted and agreed (M5.2). Temporal and spatial evolution of particle number concentration and size distribution, affected by initial concentration, background aerosols, and ventilation were considered to be major knowledge gaps. In general, the different aerosol instruments show reasonable agreement with respect the (average) particle size and particle size distribution. In both experiments ELPI showed the highest concentration followed by FMPS. SMPS showed noticeably lower concentrations in both cases.

#### **WP6 Portable active surface area aerosol monitor**

During the first reporting period partner 17 TUT has been gathering information about the means to produce ions for diffusion charging of the particles. Base on the literature survey and tests, it was decided that the corona discharge is chosen as a way to charge the particles in the developed portable aerosol monitor. The physical limits of miniaturization of unipolar corona charger have been studied with modelling and experiments. The aim of this study is to find out the physical limits on how small the charger can be and at how low voltage it can be operated. A prototype of a small corona charger has been built, evaluated. The prototype was also modelled and the model was verified against the experimental results. This part of the work has not yet been finished; some of the measurements are still on-going.

Device development is mainly partner 12 Dekati's task. During this period the focus has been in electronics development where major tasks are optimization of high voltage power supply for ECT charger, isolated power supply design and electrometer for current measurement. New concepts for all these parts are built and currently being tested. Integration for a complete system has not started. Mechanical design will start after Milestone M6, decision of the configuration of the pre-prototype (Month 20). Overall development is on time.

During the second reporting period the pre-prototype instrument has been designed and built based on the research findings from the first reporting period. Based on the previous work the corona discharge was chosen for the particle charging. Electrical components (high voltage power supply, ECT unit and electrometer) were integrated to a functional system.

The geometry of the charger was tested by TUT prior to the integration to the measurement electronics using an electrical low pressure impactor (ELPI) as reference and the charging efficiency of the charger for different size particles was measured from 8 to 130 nm. The tests results implied a good sensitivity for the pre-prototype sensor. The prototype charger was also tested with the measurement electronics to test the feasibility of the pre-prototype sensor as a whole. The prototype sensor showed comparable results with the NSAM.

The pre-prototype sensor was then manufactured by Dekati based on the tested geometry. The work will be continued with the verification of the sensor operation both using laboratory test aerosols and monitoring the working environment of different nanoparticle processes. Also the possibility of different weight functions will be evaluated.

During the third reporting period the work continued from the previous reporting period and the focus in the work was turned from device development into testing, calibration and performance evaluation of the pre-prototype sensor. Well-known laboratory aerosols were used for the calibration and the sensor response was compared to reference instruments. Deliverable D6.2 'Test report on pre-prototype instrument performance' summarizes the results of the performance evaluation. To evaluate the real-world performance, the sensor was additionally tested at different facilities both at TUT and other NANODEVICE partners. These tests were performed in co-operation with WP1, WP13, and WP14.

Based on the field tests (WP14 and other test locations) some modifications were made to the built pre-prototype sensors, focusing on improving the reliability and sensitivity of the built pre-prototypes. The main change was adding a possibility for mains (110-230VAC) power use as an alternative for battery. In long-term measurements or in monitoring purposes this was seen as a more practical approach.

#### **WP7 Size-discriminating number and surface area aerosol monitor and sampler**

During the first reporting period the main results handled single components of the system developed in WP7.

Conditioner. A suitable commercial conditioner will be chosen after the other components have been developed and the requirements for the conditioner are fixed.

Pre-Separator. A pre-separator was developed that includes a virtual impactor and a cyclone. Optimal settings for the pre-separator were studied and they were achieved.

Charger. A literature survey on existing unipolar and bipolar charger designs was conducted and the results compared. It was decided to use a unipolar charger. The charging efficiency was tested and found to be in very good agreement with literature data.

Classifier. The approach for the classifier was studied. The classifier will use the integral approach. The design is currently underway.

Counter + Size Dependent Detector. Suitable materials for the tailored particle depositions have been identified based on a literature review of the deposition characteristics and were ordered. First experiments revealed that the deposition behaviour does not exactly follow the theoretically predicted one. This may be due to incompleteness of the used theory or -more likely- due to inhomogeneities of the ordered materials.

Thermal Precipitator. Two different versions of a thermal precipitator will be available in WP7. One is an existing TP that needs to be adjusted to fit the overall system. The second TP will be a new development within WP7 and designed to deposit particles directly onto live cells by

depositing the particles directly from the airborne state and thus making in-vitro testing more representative for the true hazard in the workplace.

Electrostatic Precipitator. The development of a miniaturized ESP which can be used as stand-alone device or a component in the modular system is therefore considered to be of high priority in WP7. The designing is still on-going. Overall system design and periphery. The design of the overall system and periphery will start as soon as the designs of the single components are finalized.

During the second reporting period the work focused on the design of the single components, their evaluation and the assembly of the single components to the complete system.

Conditioner. The instrument will be kept at an elevated temperature to avoid humidity and particle-bound water to affect the measurement. Since the electrometer itself is heated and the internal pumps also release heat, the device should not need any additional heater, thus reducing battery requirements. Although the elevated temperature may cause semi-volatile particles to evaporate inside the instrument, this can be considered as a first step towards background elimination, since engineered nanoparticles are usually non-volatile. The pre-separator was developed during the first reporting period. Further experiments were conducted to investigate the effect of the pressure drop caused by the pre-separator on the efficiency of a unipolar diffusion charger, which is very similar to the charger that is used in our system.

Charger. A unipolar diffusion charger, based on the proven and established opposed flow charging principle was developed. The charger was subject to intensive investigations of the charging efficiency and the charge distributions. The charge distributions were mathematically described in a way that they can be used in the data acquisition and evaluation software. The Classifier used is of radial type that can be used in integral and differential modes. The transfer functions of the classifier were measured and mathematically describe to include them in the data acquisition and evaluation software.

Counter + Size Dependent Detector. The idea of the counter is to use a tailored deposition of charged particles on a low efficiency filter and measure the current which is then proportional to the particle number concentration. The idea of the second detector is to use a high efficiency filter and deposit all particles that penetrate the low efficiency filter and measure the total current. Five low efficiency filters (screens) have been tested that have different fibre diameters and mesh widths.

Thermal Precipitator. Two different versions of a thermal precipitator are available in WP7. One for sampling on silicon substrates for electron microscopic analysis, the other one for deposition on living cells for cytotoxicity studies. The prior one is part of the aerosol sizer and sampler whereas the latter one is a stand-alone device and referred to as 'Cyto-TP'.

Experiments were conducted to investigate the performance of the TP. A manuscript on the experimental validation of the TP has been drafted and will soon be submitted to a scientific journal. The Cyto-TP has been designed and constructed and is now ready for testing Electrostatic

Precipitator. A miniaturized electrostatic precipitator for highly efficient sampling of particles has been developed. The ESP is designed such that particles are homogeneously deposited on substrates when used along with the aforementioned charger. The substrates can hence be used for qualitative analyses of the sampled particles. The charger-ESP combination has proven to work reliably and sample even micron particles efficiently and homogeneously. Overall system design and periphery. The first pre-prototype ('prototype 0') of the aerosol sizer system has been manufactured and delivered. First measurements were carried out with the new pre-prototype and show good agreement with SMPS measurements.

During the third reporting period the work focused on: improvement of the first pre-prototype towards a clearer design by the use of an internal manifold, implementation of full flow control, improvement of the electronics towards operational stability and user friendliness and safety, testing and calibration of the screen sensor, testing and calibration of the complete system, improvement of the software, including general troubleshooting, improving user friendliness and inclusion of an intelligent decision logic for use in a tiered approach.

In addition, the Cyto-TP has been developed in WP7 that uses thermophoresis to deposit particles directly onto living cells that can be evaluated for cytotoxic effects. Extensive performance tests have been conducted with the device to verify the deposition of nanoparticles on the cells as well as test for the survivability of the cells under zero exposure conditions. These tests were directed at the proof-of-concept of the Cyto-TP.

#### **WP8 Wide-range size-resolving aerosol monitoring and sampling system**

During the first reporting period the following results were achieved. Several numerical models for particle deposition in tubes, on plates and on nets for different geometrical and material setups have been developed; Several numerical models for particle deposition in a cyclone as a function of cyclone geometry and operating conditions have been developed; Preliminary calculations with the numerical models for deposition in tubes and on plates showed that such a pre-separator would be too bulky and not suitable for a personal sampler; The models interesting from a design point of view, have been verified and tested; One of the models was employed to calculate geometry and to design a personal nanoparticle size fractionating sampler; The first prototype of the size fractionating nanoparticle personal ENP selective sampler has been manufactured Preliminary tests in Naneum laboratories shows that the performance is in the expected range of parameters; The first draft of operation instruction has been prepared and sent to WP leaders involved in testing; The first tests under SP5 are scheduled with INRS.

During the second reporting period the following results were achieved. Four prototype devices have been developed - 2 by Naneum and 2 by SU and LU to a stage where they are ready to be tested by laboratories within SP5. The devices are: a personal sampler for collecting nano sized particles in the range 2nm-5µm, an on-line monitor for detecting Carbon Nanotubes (CNT), and two modular pre-separators to measure the aerosol fraction deposited in the first extra-thoracic region and the alveolar region of the respiratory tract. Naneum CNT monitor was employed for preliminary tests at working places on the site of a European manufacture of CNT. The pre-separators are still in a process of continuous

evaluation and both the design and the measured characteristics may be modified due to recent findings  
During the third reporting period the following results were achieved on four devices:

**Device 1: Personal nano-sampler**

The device has been tested in Naneum laboratories and gives results which are in good agreement with expectations and theory. The device has been tested by partners 7 (DGUV-IFA) and 8 (INRS) as independent testers within WP13. A report has been written and submitted by partner 8 (INRS) confirming the results achieved by the sampler are consistent with expectations and theory.

The sampler has been tested in the field within WP14. Results and comments on usability have been received and form part of the final report.

**Device 2: Real time CNT Detector**

Naneum CNT monitor was employed for preliminary tests at working places on the site of a European manufacture of CNT. A CNT detector was manufactured and made available to WP14 for field testing. Feedback from initial tests indicated a tendency to blocking. The unit was redesigned and two units built and made available for further field testing. Results from field tests have been reported.

**Device 3: Sampler / Pre-separator for aerosol fraction deposited in the Gas-Exchange Region (ca. 20 nm - 5 µm).** The GE sampler/pre-separator has been tested within WP13 at the laboratories of SU, LU (Partners 10 and 26), in collaboration with WP13 at INRS and IGF (Partners 8 and 23) and within the workplace test campaign of WP14. Collaboration with P23 resulted in a redesign of the unit and retesting in the field. The results from these tests are reported in Deliverable Reports D8.3, D13.3, D14.2 and D14.3.

**Device 4: Sampler / Pre-separator for aerosol fraction deposited by diffusion in the Anterior Nasal Region (ca. 5 nm - 400 nm).** The 7ET1 sampler/pre-separator has been tested within WP13 at the laboratories of SU, LU (Partners 10 and 26), in collaboration with WP13 at INRS and IGF (Partners 8 and 23) and within the workplace test campaign of WP14. The results from these tests are reported in Deliverable Reports D8.3, D13.3, D14.2 and D14.3. It is expected that most of the comments presented in D14.3 can be addressed either in the next design version of the sampler/pre-separator or the next version of the User Manual.

**WP9 High-sensitivity optical sensor for single-particle number and mass**

During the first reporting period objectives included the investigation of several methods for the reliable detection of optical signals arising from light scattering at nanoparticles. Until now an optimized laser source and a highly sensitive receiver turned out to be the most promising approach to detect the scattered light originating from small particles in the 100 nm-regime. In order to achieve the project aim of WP9, the optoelectronic components of the measuring cell have to be improved and the opto-mechanical and electronic periphery is to be adjusted and enhanced.

During the second reporting period previously developed hardware and software modules have been assembled into a functional prototype. The

GRIMM NANODEVICE prototype consists of an optical and an electrical sensor, whose readings of an integrated electronic system merged directly into the unit and output as a data telegram. Outputs via the interfaces (either RS232 or Bluetooth) are evaluated using special software and are graphically displayed. These evaluations are already available online during measurement. The separation of measuring instrument and control system allows the user great flexibility: The device can also be used in exposed locations and / or health-endangering conditions.

Thus all required properties of the GRIMM NANODEVICE prototype and its metrics are met in the context of NANODEVICE.

During the third reporting period the development on the prototype has made it easy to use; it can be completely operated with a single button at the front site. The combination of an optical and an electrical sensor allows simultaneous measurement of a wide size range of particles:

Nanoparticles and its agglomerations can be detected with the same device, in high time resolution of a minute and without consumables. This size range includes firstly all Nanoparticles, starting from about 10 nm and ending with particles in the micrometre range at 24 microns. The measured values of the two sensors are combined internally by a special electronics and firmware, so that the user receives measurements, which do not differ from the output of a single sensor in the nature and structure. The connection between prototype and Netbook can be done via RS232 cable, via Bluetooth or via data logger. An integrated battery allows work place monitoring without external power supply. Therefore a maximum of connection flexibility for the user was achieved. Comparisons to reference technologies have shown good accordance to SMPS and OPC. For workplace measurements, first the background concentrations are to be determined in order to observe the later increase of Nano particle concentrations due to certain workplace activities.

#### **WP10 High-sensitivity MEMS-based sensor for single-particle number and mass**

During the first reporting period the following results were achieved. Development of an algorithm for detection and weighing of several particles with resonant beams. Proofing of sensor principle by measuring micro particles with cantilevers and strings. Fabrication process for micro beams with perfect clamping. Achieving an analytical model for actuation of cantilevers made from arbitrary materials.

During the second reporting period the following results were achieved. Development of an innovative method making use of the Brownian particle motion to efficiently deposit nanoparticles onto a micro resonator. Successfully developed a resonant micro-string based aerosol nanoparticle sensor pre-prototype with a particle number sensitivity competitive to commercial aerosol sensors. Introduction of a novel sensor method for nanoparticle composition measurements based on photothermal resonance spectroscopy.

During the third reporting period the following results were achieved. Airborne nanoparticles were measured using a pre-prototype in a controlled laboratory environment. Micro and nanomechanical string resonators were introduced for the efficient inertial sampling of airborne nanoparticles, facilitating the in-situ gravimetric mass and number concentration detection, and the in-situ chemical analysis with

photothermal IR spectroscopy. The sampling technique was studied with a 28 nm silica aerosol and successfully compared to a theoretical model. With the inertial sampling technique, the mass concentration of 25 nm sucrose aerosol was gravimetrically measured. The impaction of single 100 nm Ag particles was detected, which opens the door for real-time nanoparticle mass spectrometry. With the photothermal IR spectroscopy with microstring resonators, a novel sensing technique was established and it allows the chemical analysis of airborne nanoparticles, which enables the background distinction of toxic engineered nanoparticles from the natural background. Chemical fingerprint of organic nanoparticles was measured. The spectroscopy technique is sensitive enough to distinguish TiO<sub>2</sub> nanoparticles with different surface coatings. Furthermore, the analysis and distinction of single particles was shown.

#### **WP11 Catalytic and surface-chemical aerosol monitors**

During the first reporting period the detection of catalytically active ENP and detection of surface chemical functions of aerosol particles were studied. For the detection of catalytically active ENP several model ENP materials and suitable test reactions had been selected:

- Platinum: Oxidation of H<sub>2</sub> - calculated detection limit 2,4 µg\*
- Nickel: CO-Methanation - calculated detection limit 4,7 µg\*
- Palladium: Hydrogenation of ethylene (C<sub>2</sub>H<sub>4</sub>) -calculated detection limit 0,03 µg\*
- Iron Oxide (Fe<sub>2</sub>O<sub>3</sub>): Oxidation of CO - calculated detection limit 27,7 µg\*

Two different approaches were investigated for the detection of catalytically active ENP, considering preliminary laboratory set-ups: catalytic reaction on airborne ENP and catalytic reaction on deposited ENP. An improved design of the laboratory set up for catalysis experiments using deposited nanoparticles is under development. The modifications enable a combination of sampling aerosol nanoparticles and a chemical reaction in one instrument. This offers the possibility to investigate whether the calculated detection limits in the range of nanograms are achievable.

Detection of surface chemical functions of aerosol particles. The proof of principle for a simultaneous determination of particle size and a fluorescence signal on single particles was accomplished on a laboratory setup. A functional relationship between the amounts of a fluorescent dye on the surface of micron sized test particles could be established. Further work is planned using a fluorescent marker molecule specific to redox-active sites.

During the second reporting period the experimental setup for the detection of catalytically active ENP was completed. The results indicate that catalysis is indeed suitable for a substance-specific detection of ENP based on their catalytic activity. The sampling and reaction unit is already portable and allows a particle sampling directly in the breathing zone of a worker. The detection unit currently consists of a mobile infrared spectrometer. Future investigations will be directed toward a further down-sizing of the CAAM, above all with regard to the detection unit. In addition, a combination of the SRU and the heat exchanger was designed and will also be investigated.

Detection of surface chemical functions of aerosol particles. From the tests it could be shown, that the simultaneous detection of scattered

light and a fluorescence signal from individual particles can be detected. Further experiments will be conducted to enable a comparison between the two support materials for the dye. Furthermore, first experiments regarding the detection limit and the dependence of the fluorescence signal on the concentration of the fluorescent dye will be conducted.

During the third period the laboratory prototype of the Catalytic Activity Aerosol Monitor (CAAM) was further downsized by the integration of a small IR sensor. In addition, a new functionality-based metric was defined. Its usability for the assessment of workplace air was demonstrated in several experiments concerning the dependence of the catalytic signal on mass, size and support. Besides, the inherent ability of the CAAM to discriminate the target engineered nanoparticles from non-active background aerosols allows the detection of catalytically active nanoparticles even if they are attached to the background. Moreover, first investigations concerning a potential correlation of the activity measured by the CAAM in the gas-phase and a biologic activity in suspension were done. A strong correlation of the CAAM signal with the ability of the particles to produce reactive oxygen species in suspension could be observed which demonstrates the usefulness of the CAAM and its functionality based metric for a quasi-real time detection of airborne catalysts in workplace air.

In the third period of NANODEVICE, the method of detecting surface chemical functions of aerosol particles was investigated into its suitability to detect smaller particles in the range of nm which could be achieved by using TiO<sub>2</sub> agglomerates.

#### **WP12 Nanofibre monitor**

During the first reporting period the following results were achieved:

- a working setup of a AFM measurement station to measure deposited nanoparticles on surfaces situated in a Cleanroom ISO class 1 (no cross contamination possible due to clean room surroundings)
- A selection of suitable surfaces for the later usage in the fiber monitor
- First successful measurements with nanoparticles on the surfaces
- A CNT generator to produce CNTs for the later usage in the development of the fiber monitor

During the second reporting period following results were achieved:

- Design and construction of a personal sampler Version 1
- Several sampling approaches at the KIT using the CNT-generator on the KIT setting and subsequent measurements using the AFM technique at Fraunhofer IPA without any significant success. It was not possible to detect single CNTs. The agglomeration status and shape of the produced CNT was determined using TEM and SEM analysis showing that a fast scanning device using AFM will not lead to acceptable results.
- It was proposed to use light microscopic inspection instead and a modified sampler regarding some special characteristics of the CNTs.
- First optical inspections after using a modified personal sampler Version 1 showed the high potential of optical inspection. This is now being investigated further.
- Subsequent optical measurements gained different qualitative data between different market-available CNTs. This approach seems to show very good performance even in the discrimination between different CNT

manufacturers. These results will be shown at the 4M conference in November 2011 in Stuttgart as talk/poster presentation.

- First testing of the personal sampler Version 1 on a real-scenario industrial setting (in collaboration with IFA). The used parameters and sampling duration showed good deposition of particles and agglomerates. Fibrous agglomerates were visible using light microscopy. But the later preliminary performed spectroscopic analysis detected no significant CNT contamination. Further investigations are in progress.
- Design and Construction of a miniaturized personal sampler Version 2 using CNT-specific characteristics, in progress.
- Submission of a paper for the 4M conference in November in Stuttgart. The paper was accepted after minor amendments. See <http://www.4m-association.org/conference/2011>

### **During the third reporting period**

- Deliverable D12.3 Optimized nanofibre monitor as pre-prototype is ready and submitted.
- Development has been done on a CNT specific deposition method: magnetic particle collector. The collector uses a specific metric: magnetism. The method very simple to install in a personal sampler. To distinguish between background and CNTs, the particles and agglomerates on the surface are examined via Raman spectroscopy. Raman spectroscopy can detect using database correlation easily CNTs from other magnetic particles, as iron, cobalt or manganese.
- Miniaturization is ready of the system using commercially available components (for a possible fast implementation of the system in larger numbers). A personal sampling pump samples with 100 ml/min air through the magnetic particle deposition system.

### **WP13 Calibration, testing, and background distinction**

During the first year the following results were achieved. The report was completed on the adjustment of the nanoparticle calibration system for NANODEVICE which is in itself ready to use by developers. A ready-to-use version of a primary discontinuous calibration tool for coagulation aerosols and an additional prototype for a continuously working similar system was achieved. The ready-to-use version (for urban aerosol) Nano Test Facility in IGF-BGRCI in Dortmund was achieved.

During the second reporting period the following results were achieved. The nanoparticle calibration system at INRS was operational on time has been used extensively device developers in the project. The calibration tool at Fraunhofer ITEM has been further developed and demonstrated successfully in Dortmund NanoTest Facility in March 2011 and the 1st working mobile device of the calibration tool has been successfully tested. The NanoTest Facility at IGF-BGRCI is fully operational under all requirements of the NANODEVICE project and WP21 human mobility programme has been used travelling of device developers and instruments to the facility and two round robin tests have been performed. The questionnaire to assess the practicability and ease-of-use of the developed devices has been developed according to the requirements of users. It is currently applied by the device developers and measurement personnel to encourage its use with established aerosol measurement techniques and thus provide a comparison dataset for the later novel instruments from the NANODEVICE project.

During the third reporting period the following results were achieved. The nanoparticle calibration system (INRS) 'CAIMAN' has been used extensively by developers within the NANODEVICE consortium together with partner 7 (DGUV-IFA). The system's usefulness has again been demonstrated in the reporting period as at least one device has been intensely tested and further developed in Nancy (Partner 13). Progress towards objectives and details: The nanoparticle calibration system has been on time and clearly available for the use within the consortium. The calibration tool (FH ITEM) for the delivery of defined particle concentrations, based on the physical principle of particle coagulation has been further developed according to the Gantt Chart up to a stage, where it could be used in a preliminary round robin test under real conditions in the Nano Test Facility. The device is mobile and could demonstrate general applicability in IGF-Dortmund in March 2011. In the reporting period the careful test and evaluation of the calibration tool with primary methods has been going on. The tool is market ready and negotiations for exploitation and making it available for commercial use are ongoing. The Nano Test Facility has been adjusted with its existing wind tunnel and sedimentation chamber for use in the NANODEVICE project and suitable injection systems for NaCl, Diesel soot, and ENPs have been developed. In addition also high-molecular organic fluids (like DEHS) have been used to produce particles in the range between 200-300 nm. The facility has been validated with established aerosol measurement technology concerning ranges of particle sizes and concentrations as well as mixtures of particles. Device developers have continued to test their instruments at the Nano Test Facility which has provided defined aerosols. A Standard Operation Procedure was released in 2011 and has been used successfully during further work. In fall of 2012 the intended large intercomparison of pre-prototypes has been successfully performed. The questionnaire to assess the practicability and ease-of-use of the developed devices has been developed according to the requirements of users.

The version ready for field testing was delivered to WP14.

#### **WP14 Testing of the devices in the field**

During the first reporting period the following results were achieved. Current existing instruments for measuring ultrafine and nanoparticles at workplaces were reviewed and checked for parallel application during the planned workplace comparisons in WP 14. Contact with the group of external technicians in Germany has been established and procedures how to distribute devices have been discussed. The draft of the questionnaire will be distributed among them to clarify the meaning of the questions. A document on the sampling strategy (D 14.1) has been drafted in a core group and discussed with external stakeholders in Germany, which also do measurements. The draft will be discussed within the consortium. For milestone 14 it has been agreed that the partners concerned will deliver documents on the justification of their work on the pre-prototypes until summer 2010. At the next subproject 5 meeting in September these documents will be scrutinized.

During the second period the following results were achieved. The group of external technicians in Germany has been contacted and procedures for training and distribution of the new devices are under discussion. The draft of the questionnaire will be distributed among them to clarify the meaning of the questions. Milestone 14 was discussed at the SP 5 meeting in September 2010 and finalized. All instrument developers presented their concepts of feasibility, most including first results of their

realised setups. After thorough discussions all reports had been accepted. All concepts were assessed as being feasible. A document detailing the sampling methodology and intercomparison protocols for the workplace measurements (D 14.1) had been discussed and finalised in April 2011. Current existing instruments for measuring ultrafine and nanoparticles at workplaces were reviewed and checked for parallel application during the planned workplace comparisons in WP 14. A comparison of reference instruments (SMPS, ELPI, CPCs, surface area instruments, electrically detecting monitors) was conducted at the NanoTest Facility of IGF in Dortmund in June 2011. The aim was to get information on differences of all reference instruments which will be used in the field tests.

During the third period the following results were achieved. The results of the pilot study were reviewed in a SP 5/WP 14 meeting. Feedback on the performance and ease-of-use of the pre-prototypes was given to the developers, especially geared towards the further development of the pre-prototypes during the project. The questionnaire for ease-of-use from WP 13 was tested in the pilot phase and revised for use of all participants in the main study. The main study for intercomparison of the pre-prototypes and the reference instruments was prepared in a meeting of WP 14. An annex to D14.1 was prepared describing the measurement strategy for the intercomparisons in the main study. After performing the laboratory comparison in WP 13 in May 2012, the main study was carried out from July 2012 until January 2013 including the tests with the external technicians. Questionnaires for ease-of-use were adapted to WP 14 and used by all participants in the main study. The results are described in D14.3 'A report on the results of the questionnaire of the external technicians and project partners'. In total a set of 54 filled questionnaires had been evaluated. Although the state of development was very different, an overall rating of the ease-to-use revealed promising ratings better than 3 in the range 1 (very good) to 5 (bad) for all tested devices. This shows the high quality and capacity of all development partners in NANODEVICE. The results of the main study were discussed in a WP 14 meeting in January 2013 and are reported in D14.2 'A report detailing on the main intercomparison study at workplaces'. Experience from the use of the pre-prototypes in the main study was reported to the developers. A statistical analysis of data from selected measurement campaigns was performed by TNO in order to state comparability of instrument's data or to proof structural differences.

#### **WP15 Educational materials on safety of nanotechnologies**

During the third reporting period following results were achieved. Screening was done for the official public website and the internet domain <http://www.nano-device.eu> was reserved. A template for the creation of a public available internet page together with other EU-projects was developed and the later structure of the homepage was set-up. First templates for presentations and leaflets were prepared and the layout will be mostly delivered from EU-VRi. Possible places for workshops were screened (Reinraum Lounge Karlsruhe, Conferences..)

During the second reporting period the following results were achieved. The internet domain <http://www.nano-device.eu> was created and fed with all relevant information. The domain is constantly updated. The contents of the domain were commented and the logos provided by the partners. Several poster presentations were held at international conferences on NANODEVICE and a journal paper was achieved.

During the third reporting period the following results were achieved: Set-up of leaflets and posters of each device, Set-up of a questionnaire for the collection of the relevant data for the leaflets and posters from the device developers, sending the questionnaire to all device developers with two reminder loops,

Collecting all relevant data, Design and implementation of a master leaflet, Design optimization together with HSE-HSL, Proof reading of each leaflet/poster form the device developers, Finalizing the leaflets and posters, uploading the files onto <http://www.nano-device.eu> website.

#### **WP16 Data-base supporting regulations of the safety on ENP**

During the first reporting period the goal was to create structure of the databank supporting risk assessment of ENP and the goal was achieved.

During the second reporting period the following results were achieved. The database was opened to users in Mo 20. A project sub domain was created by EU-VRi and access to the website has been limited to partners in the EU-VRi team. The users can access: reference database, NANODEVICE Knowledge base and Survey tool. Reference database contains metadata about the relevant nano databases identified so far. For disseminating the project an official poster and easy-to-use brochures were created in the WP. WP16 has offered to take over the support for standardization activities after the finalization of WP17.

During the third reporting period the following results were achieved. The brochures were prepared and distributed at several occasions in particular at the following events:

- June 2012: Annual Forum for Nanosafety in Copenhagen (1st brochure)
- October 2012: SENN2012 conference in Helsinki
- November 2012: NANOSAFE 2012 in Grenoble
- February 2013: Quality NANO in Prague

**D16.3 (brochures) have been submitted.**

**D16.4 has been submitted, including a survey on standardisation activities.**

#### **WP17 Support for standardization of the safety of ENP**

During the first reporting period the following results were achieved. WP17 identified in total 30 national, European and international standards, which are of interest for the NANODEVICE consortium. The results were obtained by a literature search and analysis of standards relevant to the NANODEVICE project. Among them 14 standards are also including the nanoscale region and are thus highly relevant for the NANODEVICE project. A scientifically categorized list (4 categories) and a prioritized list (3 prioritized) of standards related to the NANODEVICE project outputs were created. A list of priority 1 standards was scientifically categorized and a list of contacts to various relevant, national and international standardization committees was compiled. A presentation on the standardization issues in general and on the status of work package 17 on the occasion of the Annual Safety Forum 2010 was given.

During the second reporting period the following results were achieved. The report on potential standardization objectives of the NANODEVICE project (D17.1), which summarized the standardization needs of the NANODEVICE consortium and on standards relevant to the project, was completed. The report on a strategy on the standardization of the NANODEVICE technologies (D17.2) summarized the work package's efforts to develop a concept of the implementation of the standardization potentials of the NANODEVICE project. The results were achieved through a survey on standardization requirements among partners. Major conclusions are that the development of European standards is a major challenge for a single EU co-funded project, even for a large-scale integrating project such as NANODEVICE. Even if adequate resources have been assigned in the planning phase the synchronization of the project life cycle with the standardization process for the development of a Technical Report (TR) or a Technical Specification (TS) will be not possible in most cases, as the project outputs are typically obtained towards the end of Research and Development (R&D) project, but are required prior to the start of a standardization project. WP17 achieved its goals and was finished as planned in the DoW in Mo 24. WP16 offered to take over the support for standardization activities after WP17 is completed.

During the third reporting period there were no WP17 activities.

#### **WP18 Establishment of an Annual Forum for Nanosafety**

During the first reporting period the Coordinator office held multiple meetings on selection of eligible candidates and created a draft list of names. Careful consideration was used to select the members with interdisciplinary backgrounds and take care that geographically Europe, USA, Asia and Africa were represented. Also having the representation of Universities, Research Institutes and small and medium-sized enterprises (SME)'s was taken into consideration. The draft list was sent to SP and WP leaders for comments and the leaders were asked to suggest names to be included in the list. Thus the final list was created. Invitations were sent and 19 persons accepted the invitation and formed the Annual Forum for Nanosafety.

During the second reporting period two Annual Forum for Nanosafety meetings were held. The first meeting was held with the first project Steering Committee meeting in Nancy, France on April 14-16, 2010. Four members from the field of standardization participated the meeting and held a Colloquium on Nanosafety Standardization. The second meeting was held with the second project Steering Committee meeting in Berlin on March 17-18, 2011. Eight members from the fields of toxicity, devices, characterization and exposure assessment, Hazard participated and held a workshop. The meetings produced fruitful discussion and the Colloquium on Nanosafety Standardization gave a boost to completion of WP17 'Support for standardization of the safety of ENP'. The second Annual Forum meeting offered an insight in wide range to the state of the art of safety research of ENPs and benefited multiple WPs.

During the third reporting period, one Annual Forum for Nanosafety meeting was held at the Steering Committee meeting that was held in Copenhagen in April 2012. Eight members were invited to hold a forum on innovation, exploitation and impact. The final Steering Committee meeting Feb. 8th 2013 focused on practical matters on ending the project and the Annual Forum members were not invited. However, the Stakeholder

group was invited to the joint meeting with the Coordination group on Jan 9-10th, 2013 to obtain societal and relevance feedback and guidance to the project for further actions by the partners to disseminate the results of the project and to assure a positive impact of results of the project for safety of nanotechnology in Europe, European Union in particular and to evaluate the innovativeness of the project and the potential for new technological innovations by the project, and the promotion of exploitation of these innovations.

### **WP19 Organizing an international congress on safety of engineered nanoparticles and nanotechnologies in 2012**

During the first reporting period the following has been decided for the International Congress: the Host, Date, Venue and the PCO. Programme: No final programme has been set yet. Speakers. No confirmed speakers have been invited yet. Practical arrangements: FIOH negotiated the venue of the Congress and has held multiple meetings internally on arranging the preliminary working timetables. All other practical arrangements, such as reserving the hotel rooms and catering, FIOH will give the task to the PCO. FIOH expects the PCO to begin working on this Congress by summer 2010.

During the second reporting period the preliminary programme has been set. The scientific programme consists of invited speakers, free oral and poster communications and a small-scale exhibition. Further education lectures are also being held on the day before the Congress starts. The speakers for the further education sessions and the keynote speakers during the scientific programme have been confirmed. On practical arrangements the Congress website is up and running. The registration fees are set. Early registration is open and it can be accessed through the website.

The address of the website is:

<http://www.ttl.fi/SENN2012>. Important dates have been set. A committee is ready for reviewing the abstracts. There are 6 different fields and 1-3 reviewers on each field have given their consent to be on the committee. An eight page leaflet has been designed with and advertisement agency, printed and it is being distributed. The teaser and A3 size poster of the teaser has been distributed by mail to partners and the Congress has also been advertised in events where NANODEVICE management has participated. Information of the Congress has been downloaded to several websites besides the project, such as the website of the NanoSafety Cluster. Social programme is ready. There is a get-together on 28th of October. Helsinki City reception is on 29th of October and the Congress dinner is on 30th of October.

During the third reporting period the SENN2012 took place on Oct. 28th-31st. 226 participants from 26 countries participated. On the third period prior the event the change of the speakers, chairs and panellists were confirmed. The abstract committee was invited and the committee members were divided in four fields. In total 155 abstracts were submitted. 38 abstracts were accepted as oral presentations in the free communication sessions and 67 were accepted as poster presentations. The programme and abstract book was designed and printed. The marketing and communication plan was made and executed. The result was that 7 sponsors and 11 exhibitors took part in the event. A press conference was organized for the national media; also a professional photographer was hired. The devices developed in the project were exhibited to ensure

maximum impact of the project. Interactiveness during the event was accomplished by using response tools with presentations and the panel discussion. Three poster awards and a special poster award were rewarded. 36 % of participants responded the internet questionnaire and the results showed that the scientific programme of the congress was interesting and that the programme was carried out in accordance with what was promised before the event. 97 % of the responders thought that the event offered them new information. Overall, the event was considered to be a success and the organizers received plenty of positive feedback.

### **WP20 Handbook on safety of engineered nanoparticles**

During the first reporting period a new book proposal was prepared, which defines the feature and targeted audience of the book. A Draft Outline of the Handbook was proposed and discussed within the WP20. The potential authors of each chapter were suggested and contacted. As a part of preparation for the handbook, we reviewed published books on environmental and human health impacts of ENP and safe production and handling of ENPs.

During the second reporting period the WP20 members (editors) have investigated existing relevant books and prepared a preliminary content outline in 2009. After receiving feedback from project partners, the editors had discussed the book content chapter by chapter in a range of meetings and telephone conferences. A more detailed content outline with an overview of the book has been prepared July 2011. We have also agreed on the book template and responsible authors for each chapter. The responsible authors will now lead the manuscript preparation of individual chapters.

The content outline will be used to communicate with authors and guide the content input in a coherent and structured way. On the other hand, the content outline is also a living document. It will be adjusted, modified, improved during the book preparation process through continuously communication with the authors. The work package members have evaluated ways for publishing and conducted contract negotiation with Springer and have been in collaboration with SP3 and SP5 on development of exposure assessment strategies.

During the third reporting period the handbook editors have negotiated with Springer regarding publishing, but due to extensive liability issues, many of the editors were very unable to sign the proposed contract. Next, the editors contacted Elsevier, and had a very successful negotiation; a contract to publish the handbook was signed with Elsevier in February 2013. The handbook originally consisted of 11 chapters; however, 2 chapters have been merged due to overlapping content. Furthermore, one chapter has been cancelled because the author was unable to deliver the chapter. We were unable to recruit a new author because this happened at a late time point. Thus the resulting handbook consists of 9 chapters.

At the deadline, 5 chapters were delivered by authors. NRCWE overtook the WP20 leadership from DNV in January 2012. This resulted in a delay in the process. The subsequent issues with the first publisher caused further delays.

### **WP21 Human mobility within NANODEVICE project**

During the first reporting period a leaflet inviting applicants for the mobility programme had been prepared and distributed among partners and heavy advertisement aimed to the consortium on the mobility programme was done by the work package members and the management office of the project.

During the second reporting period the advertisement continued, especially to the device developers within the consortium to visit the round robin tests in the Dortmund NanoTest Facility. Evaluation was done on the applications and financial issues were taken care of. In total, 10 short term mobility grants and one medium-term visit have been granted. Of the granted short-term visits, 9 have been realised. The short term travels have generally been one week, a few have been shorter. The evaluation reports clearly indicate that the exchanges have generally been regarded as highly successful. One long term applications have been granted and realised. The evaluation report indicates that the visit was very successful.

During the third reporting period it was concluded that the mobility programme can be considered successful: 25 travels were realised and the NANODEVICE project benefited from the exchange of knowledge and the testing of the new devices. In total 16 researchers (9 women, 7 men) made use of the available grants, resulting in 23 visits (some researchers applied for multiple visits). The longest stay lasted for 4 weeks, while the shortest one lasted 2 days, though shorter visits were more common. The participation of young and experienced researchers was roughly balanced. The average cost of a visit was ca. 1.400 EUR. The level of satisfaction with the visits, as it can be deduced from the evaluation reports is generally high. Most participants reported the visit as having an added value, either in terms of new methodologies learned, or in terms of setting the basis for a closer cooperation between the involved organisations. With respect to the duration, stays were shorter than initially foreseen, probably as a consequence of the high workload and tight schedule of the researchers involved.

Since the number of visits was slightly lower than initially foreseen and short term stays were preferred, the budget was not used completely. It has therefore been decided to allocate some of the remaining resources to other dissemination activities, namely the acquisition of open access rights. As a result, open access rights have been acquired, for two articles published in connection with the project

**Potential impact:**

The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results (not exceeding 10 pages)

**The potential impact**

The project results will have a marked societal impact especially on workplace safety in small and medium size enterprises and micro-enterprises through bringing into market affordable on-line measuring devices providing reliable exposure information on engineered nanomaterials. This will not only greatly increase our knowledge and understanding on the workplace exposure to these materials. It will also support regulators and decision makers in making evidence-based conclusions and actions on necessary measures to protect the workers from excessive exposure, especially the setting of occupational exposure limits (OEL) for different ENM. One can expect remarkable savings to the industry through reliable exposure information at low or affordable expenses. These outcomes of the project will also enable safe use of these materials, and promote safe production of ENM, and thereby increase the competitive edge of nanotechnologies through emphasizing safety aspects in all areas of nanotechnology applications. The project has successfully moved toward its impact objectives as demonstrated by the successful progress of the technical and impact work. Stakeholder contacts will assure a marked further impact through making the project results more visible among ETUC and Business Europe partners, occupational safety and health and research community, among governments, and the Commission as well global organizations such as OECD, World Health Organization, ISO and CEN. The ultimate goal of the project is to promote of having a positive impact on safe handling of engineered nanomaterials and safety of nanotechnologies in European Union and beyond. One important means through which these goals can be achieved is to reduce uncertainties related to nanosafety, and to promote safety thinking in all aspects related to new engineered nanomaterials and nanotechnologies. All these actions will at the end of the day promote the success of European nanotechnology industry. The European Commission celebrated the project as one of its success stories on May 20th, 2013 and at the Industrial Technology Best Project Awards 2012 in Aarhus, Denmark, the project was one of the 10 finalists out of 63 projects and received an award. An indication of the impact of the project is that one spin-off project, NanoSTAIR started during the project.

**The main dissemination activities**

During the course of the project the 26 partners of 21 work packages took part actively in conferences and meeting. Multiple oral presentation, poster presentations and thesis were held during the project. In addition to this list, the project management office presented the project posters and distributed the 3 brochures prepared during the course of the project and the SENN2012 International Congress flyers.

The SENN2012 was effective regarding dissemination. During 4 days, the presentations consisted of 20 invited speaker talks (6 further education lectures, 9 keynote- and 5 plenary presentations); the free communication presentations consisted of 38 oral and 67 poster presentations. 155 abstracts were received. According to the questionnaire sent after the

event to the participants, the result was that the dissemination value of the Congress was high.

An important dissemination activity is the preparation of the nanosafety handbook lead by the WP20. The book will focus on technical exposure measurement aspects of nanosafety without forgetting the ultimate aim of nanosafety, the prevention of harmful health outcomes due to exposure to engineered nanomaterials. The results of the NANODEVICE Project will be utilized to the extent that is possible. In any case, the goal of the book is to provide state-of-the-art information on relevant nanosafety aspects for wide audiences. An agreement has been established between the Project and Elsevier to assure effective promotion of this dissemination activity.

The Handbook on Safety of Engineered Nanoparticles collected project based information into 9 chapters:

1. Foreword by the EC representative,
2. Nanotechnology and exposure scenarios,
3. Nanomaterials and Human Health,
4. From source to dose: Emission, Transport, Aerosol Dynamics and Dose Assessment for WP Aerosol Exposure,
5. Monitoring and sampling strategy for (manufactured) Nano Objects, Agglomerated and Aggregates (NOAA); Potential Added Value of the NANODEVICE Project,
6. Quality Control of Measurement Devices - What Can Be Done To Guarantee High Quality Measurements,
7. Examples and Case Studies,
8. Safe Use of Nanomaterials,
9. Outlook.

The Coordinator of the project, FIOH also coordinates the NanoSafety Cluster (NSC) activities. The project has been widely disseminated in the various NSC events during the lifetime of the project. Furthermore, the project was disseminated in the public media.

#### **LIST OF ARTICLES PUBLISHED IN THE POPULAR PRESS**

NO.	Title	Main author	Title of the paper	Year of publication	Relevant pages
1	Nanotechnologie op de achtergrond (in Dutch)	Ulla Vogel	Vraag Aanbod, nr. 45	2012	p.4
2	Nanoteknologia tarvitsee uudenlaista turvallisuuustutkimusta (in Finnish)	Kai Savolainen	Internet newsletter	<a href="http://www.metalliliitto.fi/uutiset/-/news/394730">http://www.metalliliitto.fi/uutiset/-/news/394730</a>	2012 1
3	Nanoteknologia tarvitsee uudenlaista turvallisuuustutkimusta (in Finnish)	Kai Savolainen	FIOH Newsletter 68/2012	2012	3
4	Safety Research Needed in Nanotechnology	Kai Savolainen	FIOH Impact Sheet Oct. 2012	2012	2
5	Responsive development of nanotechnology	Kai Savolainen	Barents Newsletter on Occupational Health and Safety 2012,	15	33-35
6	SENN2012	Andreas Falck	BioNanoNet News 4/2012	2012	2
7	New Safeguards foster innovation in nanomaterials	EC writer	EC Research and Innovation news	<a href="http://goo.gl/yo6ic">http://goo.gl/yo6ic</a>	2013 2
8	NANODEVICE project coordinated by Finland is a European success story	Kai Savolainen	FIOH Press release 15/2013	2013	2

- 9 Arbetshälsoinstitutets nanosäkerhetsproject - en europeisk  
frångångshistoria  
(in Swedish) Kai Savolainen FIOH Press release 15/2013 2013 2
- 10 Työterveyslaitoksen nanoturvallisuushanke on eurooppalainen  
menestystarina  
(in Finnish) Kai Savolainen FIOH Press release 15/2013 2013 2
- 11 Nanoforskningen släpar efter (in Swedish) Kai Savolainen  
Hufvudstadsbladet 5.1.2013 2013 2
- 12 Editorial: Join the Dialogue Kai Savolainen Nature Nanotechnology 2012  
1
- 13 Broaden the Discussion Kai Savolainen Nature Nanotechnology 2013 2

## **Exploitation of results**

The project's successful culmination may have (or should have) on the general acceptance of ENPs and their positive perception by the public and users. It can be assumed that at least some of the nano technology 'scares' of recent years may have been due to inadequate knowledge and/or lack of precise regulatory limits. One issue is the lack of systematic knowledge and the devices have been out of reach for small enterprises regarding the price and regulators have not required to perform the measurements. Project will provide affordable devices and also means for exposure assessment. Regulators have the possibility to expect occupational measurements when there devices are accessible. Availability of reliable and accurate methods and devices is important to measure ENPs (and especially to distinguish between them (e.g. CNT) and naturally occurring NPs). Results of NANODEVICE project are extremely important for the overall success of Nano Technology and its further penetration in the market and public usage.

An important factor for the success of exploitation of the project's results would be:

- 1.) the enactment of regulations with specific limits for the various types of ENPs (e.g. fibrous or blocky) in the working or public environment,
- 2.) the level of allowable exposure may not be the most optimum from the point of view of health and safety, but the current (non-discriminating) methods and devices appear to be approximately sufficient
- 3.) but the new understanding of toxicity of many NPs of materials that are not toxic at larger sizes or different morphologies, has brought forth the need for new regulations and new limits

The NANODEVICE project will contribute to setting-up new standards and regulations, on the basis of the new capabilities (especially lower detection limits, reliability, identification, discrimination) between natural NPs and ENPs. The NANODEVICE Project focuses, in addition to technological innovations, to removing uncertainties around ENM safety through allowing the gathering of ENM exposure information from enterprises, especially from micro ones and SME's. Hence, the Project is in the very heart of the nanotechnology innovation challenges. The project's capability to predict its impact on nanotechnology innovations goes beyond the abilities of the Consortium, but it is likely to be remarkable. The Project has undertaken major exploitation activities especially starting in 2012 as planned, e.g. through providing an exploitation plan, identifying each partner's foreground and background, and identifying potential risks associated with the projects. Other important exploitation activities are associated with the marketing and premarketing of the devices developed as they mature. The results will have a great potential in renewing or amending the current risk assessment concept of ENM and other chemicals. The results will have a great potential in renewing or amending the current risk assessment concept of ENM and other chemicals. Each of the 21 WPs in the NANODEVICE project have defined the 32 results that the project produced and if the result is shared by several partners.

### **List of websites:**

<http://www.nano-device.eu>.