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ENVIRONMENT DIRECTORATE
CHEMICALS COMMITTEE

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Working Party on Manufactured Nanomaterials

ENVIRONMENTALLY SUSTAINABLE USE OF NANOTECHNOLOGY: PROGRESS REPORT AND NEXT STEPS

7th Meeting of the Working Party on Manufactured Nanomaterials taking place at OECD Conference Centre in Paris, France on 7-9 July 2010, starting at 10h00 on the first day

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English - Or. English

The Working Party on Manufactured Nanomaterials (WPMN) is a subsidiary body of OECD's Chemicals Committee. The aim of its programme of work is to promote international co-operation with respect to human health and environmental safety related aspects of manufactured nanomaterials.

The project Environmentally Sustainable Use of Manufactured Nanomaterials was established at the 5th WPMN (March 2009) with the aim to look at the potential of applications based on the use of manufactured nanomaterials to address major environmental challenges, as well as the potential negative impacts that such new technologies may have on environment.

As a follow-up, an Operational Plan [ENV/JM/MONO(2010)7] was developed and then endorsed by the WPMN. The operational plan is being implemented by a Steering Group (SG9), which is led by the United States and the European Commission and with the participation of delegates from Austria, Canada, Denmark, Finland, France, Germany, Japan, the Netherlands, United Kingdom, BIAC and Environmental NGOs.

To date the main focus of the work has been to gather background information on existing activities and approaches and identify the appropriate experts that can contribute to the implementation of this project. In addition, SG9 has developed some strategies for moving forward. This document is the report of progress achieved to date by SG9 in implementing the Operational Plan. It describes the work done to date, as well as the next steps. In addition, this document contains three annexes as follow: i) Annex I: Table on Potential Case Studies; ii) Annex II: National activities on life cycle assessment and nanotechnologies; and iii) Annex III: Draft elaboration of the Life Cycle Consideration Concepts.

ACTION REQUIRED:

The WPMN is invited to:

i) take note on progress achieved;

ii) volunteer to lead specific case studies;

iii) agree and support a workshop on LCA and Nanotechnologies.

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ENVIRONMENTALLY SUSTAINABLE USE OF MANUFACTURED NANOMATERIALS

Background

1. This project is being implemented by a Steering Group (SG9) comprising delegates from the United States and the European Commission (as co-chairs), together with participants from Austria, Canada, Denmark, Finland, France, Germany, Japan, the Netherlands, the United Kingdom, BIAC and Environmental NGOs.

2. Since the 6th WPMN, SG9 finalised the Operational Plan [ENV/JM/MONO(2010)7], which was further endorsed by the WPMN and declassified by the Chemicals Committee.

3. As outlined in the Operational Plan, the project is focused on enhancing the knowledge base about life cycle aspects of manufactured nanomaterials, as well as positive and negative impacts on environment and health of certain nano-enabled applications at their different stages of development. As part of this, it will consider the potential of applications based on the use of manufactured nanomaterials to address major environmental challenges such as climate change, pollution of water, soil, and air, and natural resource depletion, as well as the potential negative impacts that such new technologies may have on environment and health.

4. As a starting point, SG9 used the information generated through the OECD Conference on the "Potential Environmental Benefits of Nanotechnology – Fostering Safe Innovation-Led Growth", which was held in July 2009.

5. In order to provide additional background information to the Operational Plan, SG9 decided to further discuss the concepts that will be underlining the project. Based on the discussions, SG9 drafted a though starter (Annex I) which aim to assist in understanding how *life cycle considerations* might be used in the project. The text should also assist SG9 in implementing its work. The WPMN should note that this is an internal document to facilitate the development and understanding of key concepts for SG9 to use and that there is no intention to use this annex as an output of SG9. Also, a complementary document addressing the decision making stages is being prepared. This document is still in a preliminary stage.

Potential Case Studies

6. SG9 agreed to start to identify potential case studies (nanomaterials/applications – See Annex I), starting from the Table that was presented in the Operational Plan.

7. This table on *Potential Case Studies* is expected to be a “living” document, which should be updated based on new information, or activities undertaken within member countries. The WPMN is invited to amend this table as appropriate.

8. As a next step, SG9 agreed that specific case studies could be developed by volunteering delegations together with the support from SG9 (for example for gathering data, looking into and gathering information on what research is ongoing within each delegation etc.). The leading group/ delegation will then submit progress reports to SG9 for inputs before it is submitted to the WPMN. SG9 will also be responsible to ensure consistency of each case with the Operational Plan, and between cases as possible.

9. When agreeing to develop a specific case study, volunteering delegation should consider specific aspect including relevance, availability of ongoing research and contribution to develop Life Cycle Consideration. In addition, it was noted the importance for having a multi-sectorial engagement/ collaboration in the cases (governments, industry, Env. NGOs).

10. Delegations are invited to volunteer to lead the development of specific case studies (e.g. where work is already underway in their countries) and coordinate work between delegations.

Current Activities on LCA and Nanotechnologies

11. SG9 agreed to prepare a compilation of national activities on Life Cycle Assessment (LCA) and Nanotechnology. The current compilation is available as Annex III. This compilations was done based on; i) information provided from delegates to SG9; and ii) information extracted from submitted Tour de Table [ENV/CHEM/NANO(2010)2]. This compilation should also be kept as a living document and delegations are encourage to provide additional information if appropriate. The SG9 expect to declassify an interim report on ongoing national activities before the next WPMN Meeting.

Next Steps

12. SG9 agree to establish a smaller group with those experts on Life Cycle Assessment (LCA group). At the present time, this group is drafting a document on the LCA decision making stages, which once finalised will be put for consideration amongst SG9.

13. SG9 also discussed the possibility for holding a workshop later this year to further support the understanding of this new area of work and facilitate the implementation of this project.

14. The WPMN is invited to support this proposal and to identify national experts for this steering group 9.

15. The SG9 will finalise an interim report on national activities related to life cycle assessment and nanotechnology, which are underway, for its declassification by written procedure before the next WPMN Meeting.

ANNEX I. TABLE ON POTENTIAL CASE STUDIES[1]

15. This table presents some examples of potential case studies to be addressed by SG9.

16. Delegations are invited to amend this table as appropriate and to volunteer to lead the development of a specific case study.

Theme	Sub-Theme	Case Study	Manufactured Nanomaterials
1) Applications	Reduction of car emissions	Diesel fuel additives	Cerium oxide
		Reduction of car emissions (catalytic converters)	Aluminum oxide; cerium oxide; zirconium oxide; Perovskite; precious metals (palladium, platinum, rhodium); zeolites;
		Fuel Cells	Nanostructured polymers; aerogels; platinum; CNFs; Nanoclays;
		Thermoelectric generators	Yttrium stabilized zirconia; Nickel oxide; multi-walled carbon nanotubes; Bismuth Antimony Telluride (nanostructured); Bismuth selenide (nanostructured); quantum dots (Lead telluride, lead selenide); Silicon Germanium nanoparticles and nanowires
	Catalysis and Coatings and Treatments	Self-cleaning surfaces	Titanium dioxide
	Coatings and Treatments	Biocides	Nanosilver
		Corrosion protection	
		Flame retardants	Nanoclays; CNTs
	Energy	Batteries	Nano-structured Lithium; Carbon nanotubes
		Hydrogen generation	
		Hydrogen storage	
		Insulation	Aerogels (carbon black and silica-based); quantum dots (Cadmium selenide); aluminium oxide
		Photovoltaics	Fullerenes; nanopolymers; quantum dots; silicon nanowires
		Thermoelectrics	See above
		Lighting	Quantum dots;
	Photocatalysis	Water treatment and purification	Titanium dioxide; Polymers
		Green products through nanotechnology - reduced use of chemicals and materials	
		Strengthening/reducing materials in building structures	Nanoclays; CNTs

[1] The Table has been extracted from the Operational Plan [ENV/CHEM/NANO(2010)11].

2) Cleaner production	Catalysis	Nanoscale materials as catalysts	Titanium dioxide;
		Synthesis of nanoscale materials	Cellulose nano fibres
		Green chemistry	
		Processing of nanoscale materials	
		Using nanoscale materials to reduce pollution from processing	Titanium dioxide;
3) Other benefits	Environmental remediation	Reduction, Photodegradation, Encapsulation, Filtration, Adsorption	Iron
		Environmental sensing	Dendrimers; nanosilver
		Reduction of agricultural pollution	

ANNEX II: NATIONAL ACTIVITIES ON LIFE CYCLE ASSESSMENT AND NANOTECHNOLOGIES

17. This compilation includes specific submissions provided from delegations participating in SG9 as well as information extracted by the Secretariat from the available Tour de Tables. This is indicated as appropriate.

18. The compilation includes information from the following delegations: Australia, Austria, Canada, Italy, Korea, Germany, Thailand, the United Kingdom, and BIAC. This compilation should be used as a living document and it is expected to be updated as new information becomes available.

Australia (Tour de Table)

Australia's national medical research funding agency, the National Health and Medical Research Council (NHMRC), identified health and nanotechnology as a strategic plan issue under its 2008 project grant round, for funding commencing in 2010. From this funding round, 20 projects, totaling over $8.7 million over the life of the projects, will be funded. Research supported by NHMRC is aims to increase knowledge of the effects, potential applications and hazards of nanomaterials, and may complement and inform regulatory regimes. More information about research grants and policies is available at: http://www.nhmrc.gov.au/grants/apply/research.htm Nanotechnology and health was also identified as a strategic plan issue under the 2009 project grant round, for funding commencing in 2011. Applications opened on 8 December 2009 and closed on 17 March 2010.

Austria

- A scientific study regarding "Sustainability assessment of nano-products" focusing on nano-textiles was conducted by the Austrian Umweltbundesamt in cooperation with the University of Applied Sciences, Technikum Wien (contact: Jana Bolldorf)

- The project NanoRate includes lifecycle considerations regarding nanoproducts. Partners in this project are IFZ - Inter-University Research Centre for Technology, Work and Culture, "die umweltberatung", Österreichisches Ökologie Institute and Joanneum Research (contact: Manfred Klade, IFZ). It is funded by the Jubiläumsfonds of the Austrian Nationalbank and the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW).

Canada (Tour de Table)

Scientific Research

Canada, through the Canadian Institutes of Health Research (CIHR), has been strategically funding research into nanomedicine (nanotechnology applied to health) through its Regenerative Medicine and Nanomedicine Initiative (RMNI). As of December 2008, Canada has committed a total of $65M in grants and awards funding to these research domains. Through its most recent Request for Applications (RFA), launched in July 2009, Canada has allocated an additional $16.5M over 5 years (http://www.cihr.ca/e/39585.html). This RFA specifically includes support for multi-disciplinary teams engaged in all areas of nanomedicine, including the health impacts of nanotechnology (e.g. the interactions

of nanomaterials with biological systems, rational design of nanostructures, assessment of nanotoxicity, etc) and novel drug delivery approaches using nanotechnology.

Policy Research

Canada, in collaboration with the OECD Secretariat, is leading the next phase of OECD WPN work on developing indicators and statistics for nanotechnology, one part of which is expected to include testing of a model company questionnaire.

Germany

- Öko-Institut e.V. (Institute for Applied Ecology) is currently developing a general assessment system for evaluation of sustainability aspects of nanotechnological products. The work is part of a project supported by the UBA (Umweltbundesamt, Environmental Ministry). The assessment system is being tested in pilot projects and will serve as a basis for strategic optimization of products. BASF and Nanogate are participating in the pilot.

- Two national studies on behalf of the Federal Environment Agency (Umweltbundesamt, UBA) identified the positive effects on the environment from the application of nanotechnology. Each final report is in German and includes an English summary.

    - Environmental relief effects through nanotechnical processes and products ("Entlastungseffekte für die Umwelt durch nanotechnische Verfahren und Produkte"): http://www.umweltbundesamt.de/uba-info-medien-e/mysql_medien.php?anfrage=Kennummer&Suchwort=3777

    - Investigations into the application of nanomaterials in environmental protection („Untersuchung des Einsatzes von Nanomaterialien im Umweltschutz"): http://www.umweltbundesamt.de/uba-info-medien-e/mysql_medien.php?anfrage=Kennummer&Suchwort=3778

- The NanoKommission, a stakeholder commission on Nanotechnologies, established by the Federal Environment Ministry is actually ("NanoDialogue 2009-2011) developing life cycle considerations on potential positive and negative impacts of nano-enabled application throughout the lifecycle. The publication of the results is expected in early 2011. (Results of past "NanoDialogue 2006-2008" are documented in "Responsible Use of Nanotechnologies: Report and recommendations of the German Federal Government's NanoKommission for 2008": http://www.bmu.de/files/pdfs/allgemein/application/pdf/nanokomm_abschlussbericht_2008_en.pdf)

- Especially I´d like to draw the attention of members of SG9 on two recently published studies, which include life cycle "considerations" on some case studies (see item 1).

Italy (Tour de Table)

A very recent initiative has been announced by industry about the establishment of an European Center for the Sustainable Impact of Nanotechnology (ECSIN). The aim of the center is that of carrying out researches and studies to evaluate whether and which could be the backlash upon human and environment health, due to the exposition to nanoparticles and/or nanomaterials.

ECSIN (http://www.ecsin.eu) will be active in three main nanotech sectors, with a multilevel analysis approach:

- Interaction human health / environment
- Public perception and social/ethical policies
- Education for a responsible use

Moreover there are contacts with the Italian Ministry of Health for the creation of a first task force on the potential health risks associated with production and use of nanomaterials.

In conclusion it seems that most of the current research efforts in Italy are more focused on industrial development and application of a variety of nanomaterials than on their potential health and safety implications.

More work remains to be done in the field of health and environmental safety implications of manufactured nanomaterials.

Korea (Tour de Table)

Ministry of Knowledge and Economy (MKE)

The Ministry of Knowledge Economy (MKE) in collaboration with the Ministry of Education, Science and Technology (MEST) has initiated the programme "Strategy on Nano Fusion Industry Development" to strengthen research on the safety and social impact of nanomaterials. The MKE/KATS implemented "Risk Management Platform Technology for Nano Products (2009-2013)" which will provide an infrastructure for the certification of nano products based on a risk management system including characterization, efficacy, quality, and safety assessment along with standard development. Also MKE will set up the Risk Management Centre for Nano Products on 2010.

United Kingdom

- NanoLifeCycle: A lifecycle assessment study of the route and extent of human exposure via inhalation for commercially available products and applications containing carbon nanotubes (CNTs). The study, completed in 2009, was led by the Food and Environment Research Agency (Fera) – with participation of other UK/EU academic and industrial Experts. The study identified different available CNT-containing products on the market, and assessed the possibility of inhalation exposure to CNTs during different stages of the life cycle of lithium-ion batteries, epoxy adhesive resin, and textiles. The study also assessed the current ISO protocols for lifecycle assessment (LCA) for the relevance and adequacy to the assessment of inhalation exposure to CNT and other nanomaterials in consumer products. Common to the three product types studied was the need for mechanisms for appropriate end-of-life treatments, e.g. separate collection of (spent) CNT-containing batteries, recycling of CNT-containing batteries and textiles under controlled conditions, and appropriate disposal methods that ensure complete destruction of CNTs. The study also highlighted the need for research to address the almost total lack of exposure data on CNT-containing consumer products, and the appropriateness of end-of-life treatments.

United Kingdom (Tour de Table)

A Lifecycle Assessment study of the route and extent of human exposure via inhalation for commercially available products and applications Containing Carbon Nanotubes (CNTs)

This study, undertaken by the UK's Food and Environment Research Agency (FERA) has looked at the likelihood and possible pathways of inhalation exposure arising throughout the life cycle of a representative selection of commercially available CNT-containing products (lithium-ion batteries, epoxy adhesive resin, and textiles). For each of the products, the study analysed the possibility of inhalation exposure to CNTs during different stages of the life cycles (raw material manufacturing, product formulation, packaging, transportation, use and final disposal stages). The study also assessed the current protocols for lifecycle assessment (LCA), established by the International Organization for Standardisation (ISO), for their relevance and adequacy in relation to assessment of inhalation exposure to CNT and other nano-products.

Phase 2 of the Environmental Nanoscience Initiative announced by a UK-US funding partnership

The Natural Environment Research Council, in cooperation with the Engineering & Physical Sciences Research Council, the Department for Environment, Food & Rural Affairs (Defra), the Environment Agency and the United States Environmental Protection Agency, is in the process of considering research proposals against a major joint research effort to develop and validate predictive tools and similar conceptual models that predict exposure, bioavailability and effects of manufactured nanomaterials in the environment. In addition, researchers will be asked to develop novel techniques for detection and characterisation of nanomaterials in complex environmental and biological systems. Total funding is expected to be in the region of $8M. It is expected that successful grants will be announced in 2010.

The Engineering and Physical Sciences Research Council has just announced a four year research grant to a research consortium at Swansea and Leeds University with the aim of developing techniques to accurately measure the nanoparticle dose delivered to biological cells, track the dose dilution as cells reproduce thereby providing vital information for researchers studying any potential toxic responses. The total grant value is £1.2M.

The Engineering and Physical sciences Research Council has recently commissioned a £360k project at the University of York to improve the basic understanding of how nano-materials interact with cells and in particular to investigate the toxic effects triggered by nanoparticles through oxidative stress.

The UK Department for Environment, Food & Rural Affairs (Defra) has recently commissioned Oakdene Hollins Ltd to develop a methodology for estimating, in monetary terms, the benefits of nanotechnology. Whilst there have been several studies considering the potential benefits, or market value, of nanotechnology a widely accepted methodology does not currently exist. The project will involve testing the methodology on nanotechnology applications falling within Defra's remit (e.g. land remediation, water treatment, agriculture) to assess their potential benefits to the UK. However, the resulting methodology will be capable of being applied to any current or emerging nanotechnology applications or products and will therefore be of use to governments, industry and academia throughout the world.

Research programmes or strategies which focus on life cycle aspects of nanomaterials

The Natural Environment Research Council, in cooperation with the Engineering & Physical Sciences Research Council, the Department for Environment, Food & Rural Affairs, the Environment Agency and the United States Environmental Protection Agency, has funded three research consortia through a major joint UK-US initiative to develop and validate predictive tools and similar conceptual models that predict exposure, bioavailability and effects of manufactured nanomaterials in the environment. A total of $12M will be invested across these projects which will investigate both terrestrial and aquatic ecosystems and cover a wide range of disciplines including material science, detection and characterisation, biological interactions (ecotoxicology), modelling, risk analysis, and novel technology development. Full details are yet to be formally announced. Contact Dominique Balharry DOLH@nerc.ac.uk

Launch of the "UK Nanotechnologies Strategy: Small Technologies, Great Opportunities"

The UK Government's Nanotechnologies Strategy was published on 18 March 2010.

The Strategy was informed by an evidence gathering consultation exercise, which ran from July-October 2009. The data collected was analysed and considered during the development of the UK Nanotechnologies Strategy.

The Strategy will ensure that the various governance issues are effectively coordinated and demonstrate the work that is being done across UK different departments, agencies and organisations. The aim of the Strategy is that The UK's economy and consumers will benefit from the development of nanotechnologies through Government's support of innovation and promoting their safe, responsible and sustainable development in a way which reflects the needs of the public, industry and academia.

- The UK Government Strategy makes a number of commitments including:
- The establishment of a new Nanotechnologies Collaboration Group to facilitate ongoing communication and collaboration between Government, academia, industry and other interested parties;
- A new website to keep the public informed about work on nanotechnologies;
- An ongoing portfolio of Government and publically-funded research into a wide range of crucial EHS issues; and
- The UK continuing to contribute to international work programmes including those of the OECD.

The Strategy can be accessed via the following link: http://interactive.bis.gov.uk/nano/

Thailand (Tour de Table)

The National Nanotechnology Center, Thailand, (NANOTEC) was founded on August 13th, 2003 as an autonomous agency under the umbrella of the National Science and Technology Development Agency (NSTDA), Ministry of Science and Technology (MOST). Our vision is to create micro- and nanotechnologies that would enrich Thai industries, protect the environment and give rise to niche innovative products, processes, and competitiveness in the global market. Our missions are to establish, support and promote the nanotechnological development of the country through research innovations, technology transfer, human resource development, and infrastructure. Specifically, we (1) prepare the National Nanotechnology Road Map, (2) act as the national coordinating body between academia, industry and government, (3) set up collaborative network by assembling a critical mass of high-caliber researchers

and educators on nanotechnology, (4) identify and focus on niche areas and products in nanotechnoloogy thus enhancing Thailand's competitiveness, (5) disseminate knowledge and transfer nanotechnoogy to industrial and governmental sectors, (6) carry out research in certain core or common areas in nanotechnology, and (7) provide essential analytical nano-scale instruments for sharing with other nanotechnology research laboratories.

European Commission

In March 2010, a "*Compendium of Projects in the European NanoSafety Cluster"* was published. ftp://ftp.cordis.europa.eu/pub/nanotechnology/docs/compendium-nanosafety-cluster2010_en.pdf
The report provides more details about the projects listed below (except the Prosuite project). More information about the EU funded projects can also be found at www.nanosafetycluster.eu.

NANOSUSTAIN *Development of sustainable solutions for nanotechnology-based products based on hazard characterization and LCA*. EU Research Framework Programme 7. Start date: 2010-05-01 End date:2013-04-30;

The objective of NanoSustain is to develop innovative solutions for the sustainable design, use, recycling and final treatment of nanotechnology-based products This will be achieved by a comprehensive data gathering and generation of relevant missing data, as well as their evaluation and validation, for specific nano-products or product groups in relation to their human health and environmental hazards and possible impacts that may occur during after-production stages. Although production of nano-materials is rapidly increasing, our knowledge about possible health and environmental effects associated with these materials is still rather poor. This lack of knowledge calls for more research. Due to their small size, nano-particles behave different than their chemical analogues. They can be taken up easily and in a unique way with possible adverse effects in man and organisms. Assessing their hazard is complex and needs new approaches and a close international cooperation. NanoSustain will address the questions

- how and to what degree society and the environment will be exposed to nano-materials and associated products, and
- where do these particles end up? Expected results will improve our present knowledge on the impact and fate of these particles after entering economic and natural cycles.

Based on results from hazard characterization, impact assessment and LCA, the project will explore on a lab-scale new solutions for the design of selected nano-materials and associated products and their sustainable use, recycling and final treatment. As the concerned nanotech industry will actively participate in the planned project, NanoSustain will set the ground for the development of new sustainable products and industrial applications, and hence help to strengthen competitiveness of the European nanotechnology industry.

http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_FR&ACTION=D&DOC=1&CAT=PROJ&QUERY=01282168dd1d:9f69:410e5aca&RCN=94362

PROSUITE *Development and application of standardized methodology for the PROspective SUstaInability assessment of Technologies*. EU Research Framework Programme 7. Start date:2009-11-01 End date:2013-10-31

The main goal of PROSUITE is to develop a framework methodology, operational methods and tools for the sustainability assessment of current and future technologies over their life cycle, applicable to

different stages of maturity. The project will apply the methodology for four technology cases with close consultation of the stakeholders involved, which includes cases from biorefineries, *nanotechnology*, information technologies, and carbon storage and sequestration. PROSUITE will show

- how to combine technology forecasting methods with life cycle approaches
- how to develop and possibly combine the economic, environmental and social sustainability dimensions in a standardized, comprehensive, and broadly accepted way.

PROSUITE will create a solid research basis for technology characterization, including the identification of decisive technology features, basic engineering modules for estimations of material flows and energy use, and learning curves. For the economic assessment, methods for the assessment for economic and sectoral impacts of novel technologies will be developed and combined with background data for scenario-based life-cycle inventory modelling. For the environmental assessment, state-of-the-art environment indicators will be proposed together with targeted method development for the assessment of geographically explicit land and water use impacts, metal toxicity and outdoor nanoparticle exposure. For the social assessment, a set of quantitative and qualitative social indicators will be selected via participatory approaches, setting the standard for future assessments. The use of various multicriteria assessment methods will be explored to aggregate across indicators. The methods developed will be part of a decision support system, which will be output as open source modular software. http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&QUERY=0129036c7fbf:65d7:5981dbc2&RCN=92592

NANOPOLYTOX *Toxicological impact of nanomaterials derived from processing, weathering and recycling of polymer nanocomposites used in various industrial applications*. EU Research Framework Programme 7. Start date:2010-05-01. End date:2013-04-30

The project NANOPOLYTOX will evaluate the toxicological impact of nanomaterials included in polymer nanocomposites, highly used in various industrial sectors, during their life cycle. The toxicological profile will be correlated with the changes in the physical and chemical properties of the nanomaterials during the artificial aging/weathering process of the polymeric nanocomposites. Raw nanomaterials and extracted nanomaterials will be characterized at different stages of their life cycle and their toxicity profiles will be obtained via in vitro and in vivo toxicity studies. The results from the in vivo studies will be used for the evaluation of the biological and environmental fate of nanomaterials. All the data generated during the project (physical, chemical and toxicological data) will be considered for the development of the novel LCIA methodology to apply to nanomaterials. These studies will also be taken into account for the selection of adequate digestion and extraction methods to separate the nanomaterials from the polymeric matrices. Moreover, optimization of these methods will facilitate the development of recycling techniques that will be applied in the end-stage of polymer nanocomposites. Disposal of the extracted toxic and/or innocuous nanomaterials will be carried out by mechanical and chemical recycling techniques. The chemical recycling technique will be based on a new separation method consisting of nanofiber filters to separate efficiently the raw nanomaterials from the polymeric matrices and re-use them in new applications. Finally, the nanofiber filters containing toxic nanomaterials will be immobilized in xerogel matrices by sol-gel processes and sintering.

http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_LANG=EN&PJ_RCN=11298812&pid=0&q=4C6B99B07A250605CB870D46BC247E2C&type=sim

NANOFATE *Nanoparticle Fate Assessment and Toxicity in the Environment*. EU Research Framework Programme 7. EU Research Framework Programme 7. Start date:2010-04-01. End date:2014-03-31

The objective of NANOFATE is to fill knowledge and methodological gaps currently impeding sound assessment of environmental risks posed by engineered nano-particles (ENPs). The vision is to assess environmental fate and risk of ENPs from high-volume products for which recycling is not an option; namely; fuel additive, personal care and antibacterial products.

Two market ENPs from each product (CeO2, ZnO, Ag of varying size, surface and core chemistries) will be followed through their post-production life cycles i.e. from environmental entry as spent product, through waste treatment to their final fates and potential toxic effects. This will test the applicability of current fate and risk assessment methods and identify improvements required for a scientific assessment of ENPs at an early stage. Such systematic study of the environmental fate and toxicity of selected ENPs will address:

1. Design, tagging and manufacture of ENPs
2. Analysis of ENP interactions with abiotic and biotic entities
3. Generating predictive models for ENP exposure in waters and sludge-amended soils
4. Studying the fate and behaviour of ENPs through wastewater treatment
5. Determining acute and chronic ecotoxicity
6. Assessing effects of physico-chemical properties on ENP bioavailability
7. Defining mechanisms of uptake, internal trafficking, and toxicity
8. Developing spatial RA model(s)
9. Improving understanding of ENP risks Methodology:

http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_LANG=EN&PJ_RCN=11268644&pid=0&q=4A431954F4A8C66B88BE665C45A266E0&type=sim

NANOHOUSE: Life *Cycle of Nanoparticle-based Products used in House Coating.* EU Research Framework Programme 7. Start date:2010-01-01. End date:2013-06-30.

Objective: NanoHOUSE intends to create a holistic and prospective view on the Environmental Health and Safety (EHS) impacts of nanoproducts used in house building, namely paints and coatings. The latter are using relatively high amounts of Engineered NanoParticles (ENPs) such as nano-Ag and nano-TiO2 which will be investigated. A new Life Cycle Thinking (LCT) approach will be developed gathering two complementary aspects: Investigation of risks and opportunities during the product life cycle as well as Life Cycle Analysis (ISO 14040). LCT will collect information on EHS impacts throughout all life cycle stages of the nano-products, identifying the data gaps which will guide the research work. NanoHOUSE will generate reliable scientific information for the missing data and will develop appropriate methods to analyze the potential EHS impacts of nano-products.

NanoHOUSE first task will be to quantify the actual sources of ENPs during the use and ageing of actual coatings (weathering, renovation, demolition and final disposal). The project will then characterize the environmental compartments significantly impacted by ENPs released from nano-products, measure ENPs concentrations and states in those compartments, and investigate their fate in order to increase the knowledge regarding exposure to ENPs with a view to reducing the risks. NanoHOUSE will study the environmental behaviour and the toxicological effects of actually released ENPs (aged ENPs) and compare them with pristine ENPs.

Finally, NanoHOUSE will improve the solutions for end of life treatments regarding ENPs release in the environment. Main outcomes of the project will be a scientific risk evaluation of nano-products used in building, solutions to improve their competitive and sustainable development by decreasing their potential to release ENPs, and contributions to standard tests for their certification. The NanoHOUSE consortium involves 5 research/academic partners and 4 industrial manufacturers of which 1 SME.

http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_LANG=EN&PJ_RCN=11268654&pid=0&q=02943F90D75AFE5CA87B1EB11E33D935&type=sim

NANEX: *Development of Exposure Scenarios for Manufactured Nanomaterials.* EU Research Framework Programme 7. Start date:2009-12-01. End date:2010-11-30.

Objective: Nanotechnology is a fast growing industry producing a wide variety of manufactured nanomaterials (MNMs) and numerous potential applications. Consequently, the potential for exposure to humans and the environment is likely to increase. Human exposure to MNMs and environmental release of these materials can occur during all the life cycle stages of these materials. For each stage of the life cycle of an MNM, exposure scenarios will need to be developed that effectively describe how exposure to humans and the environment occur and what measures are required to control the exposure. The aim of the NANEX project is to develop a catalogue of generic and specific (occupational, consumer and environmental release) exposure scenarios for MNMs taking account of the entire lifecycle of these materials. NANEX will collect and review available exposure information, focussing on three very relevant MNMs:

- high aspect ratio nanomaterials - HARNs) (e.g. carbon nanotubes)
- mass-produced nanomaterials (e.g. ZnO, TiO2, carbon black)
- specialised nanomaterials that are currently only produced on a small scale (e.g Ag)).

The exposure information will include both quantitative (measurement results) and qualitative contextual exposure information (risk management measures). We will also review the applicability of existing models for occupational and consumer exposure assessment and for environmental release from these scenarios. We will carry out a small number of specific case illustrations and carry out a gap analyses of the available knowledge and data. Finally, we project knowledge will be disseminated to relevant stakeholders, taking into account other relevant activities that are taking place in this field.

http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_LANG=EN&PJ_RCN=11275710&pid=0&q=BBF165CF3045F30EEB5A1E1739774CC9&type=sim

European Commission (Tour de Table)

The Nano Action Plan 2010-2015: Impact assessment

The Impact Assessment for the new Nanotechnology Action Plan 2010-2015 is based on three pillars:

- Strengthen the societal dimension of Nanotechnologies
- Ensure high levels of consumer, worker and environmental protection
- Stimulate innovation and sustainable growth in the EU with Nanotechnologies

For each of these pillars, the problems and the objectives are identified. After that, three policy options are proposed, of which the societal, environmental and economic impacts, as well as the impacts on the three pillars are assessed. The preferred option will eventually lead to the new Action Plan.

Specific actions, covering the three pillars, will be defined in the Action Plan itself. The new Nanotechnology Action Plan 2010-2015 is expected to be adopted by the European Commission on November 2010.

Key Enabling Technologies:

Nanotechnology has been identified as one of the Key Enabling Technologies (KETs) in the Commission Communication 512(2009) from September 2009. As foreseen in the Communication a recently selected High Level Group will assess the competitive situation of the relevant KETs and develop a detailed strategy and recommend appropriate policy measures with an associated roadmap for a more effective deployment of KETs in Europe. As such, the KETs forms part of the new EU2020 strategy and are highlighted under two EU flagship initiatives, namely the "Innovation Union" and "An industrial policy for the globalisation area". The HLG is expected to hold a first meeting on the first half of July 2010.

http://ec.europa.eu/enterprise/sectors/ict/key_technologies/index_en.htm

TEC (Transatlantic Economic Council) Innovation Workprogramme - Nanotechnologies workstream

As part of the forthcoming TEC Innovation Workprogramme which the European Commission and the US Department of Commerce are currently discussing, both parties will be agreeing to exchange information on how to create socio-economic value around nanotechnologies and how to promote a culture of openness to speed up market development. Work will also include the identification of barriers to the development of nanotechnologies and associated trade flows, such as inadequate (insufficient or too strict protection of) IPRs and also education/skills related barriers. Furthermore, this work could serve to make progress in the adoption of common US-EU business practices so as to influence emerging markets for nanotechnology products. Work should build on the work being done by international organisations such as the OECD and the ISO. First deliverables are expected in 2011.

Business and Industry Advisory Committee (BIAC): NIA

Benefits of Nanotechnologies:

The NIA recently commenced a project entitled 'Valuing Nanotechnologies - Methodology for estimating, in monetary terms, the benefits of nanotechnology'.[2]

This project will address this issue by developing a methodology to quantify the value of a nanotechnology in comparison to conventional products. The methodology will be flexible; enabling specific geographic regions or industry sectors to be analysed in order to identify where the monetary benefit of the nanotechnology resides. It will also describe how the benefits are apportioned between users, manufacturers and the wider economy/environment. To simplify the methodology, various proxies and assumptions will be explored, in order to reduce the need to gather large amounts of information. On completion of the project the results and findings will be presented to the OECD to encourage developing a consistent methodology for valuing nanotechnology.

[2] Follow this link to find out more about the 'Valuing Nanotechnologies'-Project: http://www.nanotechia.org/content/activities2/current-projects/valuenanotech20100400/

Commercialisation:

The NIA is currently conducting research into Best Practices for IPR and Technology Transfer in Nanotechnology Developments.[3]

The Nano2Market project aims to develop and provide guidelines for technology transfer, rules for IPR and license agreements and license models in nanotechnology development projects. To achieve these objectives the project team is constructing value chains of the transfer of each technology, and aims to analyse specific representative applications of the different areas of the nanotechnology R&D European strategy: medical applications, information technologies, energy, materials, manufacturing, instrumentation, food, environment and security. The objective is to classify the technology application areas of nanotechnologies into different clusters according to: development cost, time-to-market, complexity of licensing, etc. In parallel, the actual and forthcoming market will be mapped and analysed according to competitiveness, geographical area, development potential, risks, etc. Specific data mining tools will help to conclude the key worldwide actors of development and commercialisation of the different technologies. Actual IPR cultures and technology transfer rules will be listed according to the features of their market and technology; matching thee IPR and technology transfer models with the concluded value chains and market and technology maps will result in the recommendation of best practice business models and efficient rules for technology transfer.

In agreement with the OECD WPN, the findings of the Nano2Market project final Nano2Market Dissemination event will be shared with the OECD WPN.

Market-Specific R&D:

The NIA is conducting a research project entitled Transforming the future of heat management (NanoHex).

The world's largest collaborative project for the research and development of nanofluid coolants, NanoHex comprises of a consortium of 12 leading European companies and research centres. It has been funded by a €8.3 million Seventh Framework Programme grant, together with investment from the consortium themselves.

Using promising research results from previous work by the consortium, NanoHex aims to develop and optimise the processes for the production of high performance nanofluid coolants for use in industrial heat management. As well as an analytical model that will predict the nanofluid's thermal performance; something that has not yet been achieved.

Nanofluids (carrier liquids into which particles smaller than 100 nanometers have been dispersed) have shown significantly enhanced thermal properties in comparison to traditional cooling fluids. Two separate methods will be employed to produce the purpose designed nanofluids during the project. A single-stage process will employ wet chemical synthesis to form and disperse tailored nanoparticles within a carrier fluid and a two-stage batch process will add pre-produced nanoparticles to a carrier fluid.

[3] Follow these links to find out more about the Nano2Market project: http://www.nanotechia.org/content/activities2/current-projects/niaprojectnano2market/ or http://www.nano2market.eu/

Using both Risk- and 'Life Cycle'-Assessments, NanoHex will also evaluate the health and safety of nanofluid coolants and their potential impact on the environment. These results will then form an important component in assessing the final products overall economic viability.

Ultimately, the project will develop two different demonstrators for the cooling of Data Centres and Power Electronic Components, in order to illustrate the viability of using such nanofluids to reduce energy consumption and operating costs, cut carbon emissions, extend product reliability and enable the development of more sustainable processes and products.

ANNEX III. DRAFT ELABORATION OF THE LIFE CYCLE CONSIDERATION CONCEPTS

This text is a though starter being developed by SG9 to assist in understanding how ***life cycle considerations*** might be used in the project. It aims to provide a background to the Operational Plan on some specific issues and assist SG9 in the further work. There is no intention to use this annex as an output of SG9, but rather to facilitate the development of key concepts and thus the implementation of the project.

A complementary document addressing the decision making stages is being prepared.

Thought starter – Elaboration of the Concepts

Nanotechnology has the potential to address major environmental challenges via a number of novel applications based on the use of manufactured nanomaterials[4]. Examples can be found in areas like flexible photovoltaics to enhance and expand the use of solar power compared to existing solar cell and traditional power sources, nano-based water purification techniques to reduce the massive infrastructure necessary for providing clean drinking water today, new generations of batteries for mass transportation with low or no carbon dioxide emissions, etc. From an environmental policy perspective, it will be important to explore how nanotechnology may be used directly or indirectly to address environmental problems by improving existing products or processes with regard to energy or material efficiency, or otherwise reduce environmental or health impacts.

Novel nano-enabled applications may however also cause unwished, negative impacts on health or environment, e.g. in terms of exposures to hazardous products, or demands for high energy inputs in the manufacturing process. To identify any potential negative impacts, a holistic life cycle of a product or an application needs to be considered, preferably at the early stages in research and development, when problems are more easily addressed.

To support a safe and sustainable development of nanotechnology, it would be desirable to have methods and tools available to analyse both positive and negative impacts in a systematic manner. Such tools could become important instruments for making balanced assessments of overall impacts to support decision makers in different situations and at different stages in the development and use of an application; from investments into research, innovation, product development, scaling-up of production, marketing, to end-of-life and regulatory decisions.

The OECD conference 15 - 17 July 2009 on the "*Potential Environmental Benefits of Nanotechnology – Fostering Safe Innovation-Led Growth"* generated ideas for the WPMN continued work in the area and the SG9 steering group was subsequently set up to continue the work. The aim of this thought starter is to complement the SG9 operational plan and to clarify some of the conceptual ideas behind the project; in particular the concept of "life cycle considerations" as compared to life cycle assessments and the reasons for limiting the scope of SG9 to study "positive and negative environment impacts" as compared to risk/benefit and sustainability assessments.

[4] For this project, these applications will be called *nano-enabled applications* (to indicate that manufactured nanomaterials are used for some performance improvement in applications).

Life Cycle Considerations

According to the operational plan the SG9 will focus on "enhancing the knowledge base about life cycle aspects of manufactured nanomaterials, as well as positive and negative impacts on environment and health of certain nano-enabled applications at their different stages of development". For these purposes, tools and frameworks based on *life cycle considerations* should be developed and applied to selected cases of nano-enabled applications.

Life cycle considerations can be described as methods based on the principles of life cycle assessment (LCA) – but with increased degrees of flexibility. LCA is a clearly defined methodological framework reported in the ISO 14040/14044 standard that can be used for evaluation of overall impacts of a product system and for comparing different options/products/applications. LCAs are however work intensive and require specific expertise. It is also not certain whether LCAs would be the optimal tool for all aspects of SG9 work, and it was therefore decided to introduce the more general concept of life cycle considerations. This will leave sufficient freedom to develop the concepts further according to the needs of SG9. For this purpose SG9 has endorsed the idea of setting up a smaller "life cycle" expert group within SG9 to support the conceptual and modelling work.

In the discussion during the development of the operational plan, life cycle considerations were defined as tools that "will take into account the potential positive and negative health and environmental impacts of a nano-enabled application throughout the lifecycle of the material from its extraction to its disposal/recycling". This definition covers:

- positive contributions in terms of directly ameliorating an existing environmental problem, or reducing negative impacts on environment and health compared with other technologies;
- negative unwished impacts on health, environment, energy and natural resource use; these could e.g. relate to greenhouse gas emissions, acidification, smog, ozone layer depletion, eutrophication, eco- and human-health toxicity, habitat destruction, desertification, land use as well as depletion of rare minerals and fossil fuels.

Furthermore, it should be possible to apply the life cycle considerations at the various stages where decisions may need to be taken – from investments into research, innovation, product development, scaling-up of production, marketing, and finally considerations of end-of-life and regulatory issues. In particular, integrating life cycle considerations into the research and innovation stages will help inform decision makers early in the process on how novel applications could be exploited in a safe and sustainable manner, where potential negative impacts could be addressed upfront.

As SG9 addresses decision-making at a variety of stages and also for a variety of applications, challenges will be to develop tools and frameworks that are sufficiently simple and that can deal with uncertainties and data scarcity. Although the approach will unlikely be able to provide "yes or no" answers, a system describing positive and negative impacts in physical terms could be used as an input for more complex and aggregated socio-economic assessments.

To provide some concrete ideas of the impacts that will need to be looked into[5]:

- To what extent do savings in energy efficiency compared to those of conventional devices/products balance the energy consumption used in producing nanomaterials?
- Which specific phase in the life cycle (e.g., manufacturing, end-of-life) dominates resource consumption?
- Are there any issues in end-of-life management that are specific to nanomaterials, especially recovery and reuse or recycling?
- What are the key eco-toxicity and human-toxicity potentials for nanomaterials and auxiliary chemicals, e.g. those used for production of the nanomaterials?
- How do the life cycles of devices/products using nanomaterials compare with those of conventional devices/products?
- What are the geographical impacts of devices/products using nanomaterials

It is clear that SG9 will contribute with new information to the WPMN, and there will be strong links and building on knowledge generated by other WPMN SGs (like health and environment toxicity, exposures and risk assessments). The 14 representative nanomaterials are those most commonly used in the case studies to be selected by the SG9 delegations

Why not full risk-benefit and sustainability assessment (including socio-economic dimension)?

Ultimately, there may be a need for decision makers to have a fuller sustainability assessment of novel nano-enabled applications and full risk/benefit analyses. In several policy and legislative areas, the concept of risk/benefit balance already underlies the framework of decision-making. However, there were several considerations about these issues in the development of the SG9 operational plan:

1. Although the concept of risk/benefit is reasonably well articulated for certain aspects of direct hazards and economic benefits, integrating broader environmental and economic impacts have proven more difficult. Lacking are e.g. valuation methods and methods to compare and add different types of impacts. Attempts to develop aggregated indicators have therefore so far not resulted in changes to actual governmental decision-making processes;

2. Problems also arise when translating physical impacts (like emissions expressed as particle or mass concentrations) to monetary values, which often are needed to create aggregated indicators. The methods for economic valuation (damage costs, contingency valuation, etc.) add additional degrees of uncertainty; in particular this is difficult in areas like nanotechnology where the knowledge about the physical impacts is at present scarce and uncertain;

[5] Based on "Nanotechnology and Life Cycle Assessment, Workshop in Washington DC, 2-3 October 2006, Woodrow Wilson Publication (organised by US EPA, EC and WWC):

3. Highly aggregated indicators weighing risks and benefits may also be too value laden for productive discussion in an area such as nanotechnology where the situation is already quite contentious. There are equity issues like "who accrues the benefits" and "on whom do the risks fall". In many cases in the past, the people who have been placed at greatest risk have not been the same people who have reaped the greatest benefits from new technologies.

It was consequently decided to limit the scope of the work in SG9 to focus on the positive and negative impacts on health, environment, energy, raw materials use, i.e. in a life cycle perspective and in physical terms.

Broader aims of SG9

In spite of the deliberate limitations of SG9 work to focus on the environment and health dimension, the project may potentially contribute to the following broader tasks.

- **Greener and sustainable growth:** The work of SG9 may feed into the larger context of fostering innovation ultimately leading to greener and sustainable growth, including the *OECD Green Growth Strategy* announced by ministerial declaration on 25 June 2009. This broader work may include projects that incorporate the assessment of environmental impacts into a broader evaluation of socio-economic benefits; utilize this type of analysis to identify priorities and directions for future technological innovations; and identifying affordable drivers for and surmountable barriers to developing these green technologies.

- **Informing the environmental policy debate:** In most environmental policy areas, the potential of nanotechnology applications has not yet been considered. One reason is that much of the early research has not yet developed into commercially viable products. Further barriers may include concerns regarding potentially increased negative impacts. With a solid analysis showing both potential contributions to solve environmental problems and full transparency of potential downsides and how these could be addressed, information problems could be overcome. To understand the full potential of what nano-enabled applications may offer, comparisons to other existing technologies will be needed.

- **Guidance for investments into research and innovation:** Making life cycle considerations would be useful to determine which areas are expected to have significant contributions to address environmental concerns and lower potential negative impacts on health, environment, energy and natural resources. An *iterative* process applied during the innovation stages should enable the identification of potential unintended negative impacts early on. Focus could then be given to work on improvements in the problematic areas to achieve "best possible technology solutions".

- **Support for chemical and nano-safety policymaking and legislation:** The work will focus on nano-enabled applications involving some of the representative nanomaterials in the WPMN sponsorship programme. As nanotechnology develops, more sophisticated applications will appear where nanomaterials are integral parts of more complex systems. Such new applications may replace existing technologies based on traditional materials. A perspective that includes broader life cycle considerations beyond a risk assessment may aid policymakers in reaching decisions in situations involving uncertain or limited data. In particular, there may be a need to identify nano-enabled applications with a high potential to reduce overall environmental impacts but where potential specific unintended negative impacts need to be managed or when choosing between substitutes.

- **Communication:** The debate about nanotechnology would profit from examples at the application level where both potential positive and negative environmental impacts are presented in a consistent framework. It would facilitate communication between decision makers, stakeholders and the public at large by providing common reference points regarding environmental impacts.

REFERENCES: LIFE CYCLE AND NANOTECHNOLOGY:

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