Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

21-Jan-2016

English - Or. English

ENV/JM/MONO(2016)2
Unclassified

ENVIRONMENT DIRECTORATE
JOINT MEETING OF THE CHEMICALS COMMITTEE AND THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY

PHYSICAL-CHEMICAL PARAMETERS: MEASUREMENTS AND METHODS RELEVANT FOR THE REGULATION OF NANOMATERIALS

OECD Workshop Report
Series on the Safety of Manufactured Nanomaterials
No. 63

JT03389225

Complete document available on OLIS in its original format

English - Or. English

OECD Environment, Health and Safety Publications

Series on the Safety of Manufactured Nanomaterials

No. 63

PHYSICAL-CHEMICAL PARAMETERS: MEASUREMENTS AND METHODS RELEVANT FOR THE REGULATION OF NANOMATERIALS

Environment Directorate
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
Paris, 2016

Also published in the Series of Safety of Manufactured Nanomaterials:

No. 1, *Report of the OECD Workshop on the Safety of Manufactured Nanomaterials: Building Co-operation, Co-ordination and Communication (2006)*

No. 2, *Current Developments/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 1st Meeting of the Working Party on Manufactured Nanomaterials (2006)*

No. 3, *Current Developments/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 2nd Meeting of the Working Party on Manufactured Nanomaterials (2007)*

No. 4, *Manufactured Nanomaterials: Programme of Work 2006-2008 (2008)*

No. 5, *Current Developments/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 3rd Meeting of the Working Party on Manufactured Nanomaterials (2008)*

No. 6, *List of Manufactured Nanomaterials and List of Endpoints for Phase One of the OECD Testing Programme (2008)*

No. 7, *Current Developments/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 4th Meeting of the Working Party on Manufactured Nanomaterials (2008)*

No. 8, *Preliminary Analysis of Exposure Measurement and Exposure Mitigation in Occupational Settings: Manufactured Nanomaterials (2009)*

No. 9, *EHS Research Strategies on Manufactured Nanomaterials: Compilation of Outputs (2009)*

No. 10, *Identification, Compilation and Analysis of Guidance Information for Exposure Measurement and Exposure Mitigation: Manufactured Nanomaterials (2009)*

No. 11, *Emission Assessment for the Identification of Sources and Release of Airborne Manufactured Nanomaterials in the Workplace: Compilation of Existing Guidance (2009)*

No. 12, *Comparison of Guidance on Selection of Skin Protective Equipment and Respirators for Use in the Workplace: Manufactured Nanomaterials (2009)*

No. 13, *Report of an OECD Workshop on Exposure Assessment and Exposure Mitigation: Manufactured Nanomaterials (2009)*

No. 14, *Guidance Manual for the Testing of Manufactured Nanomaterials: OECD Sponsorship Programme (2009)*

No. 15, *Preliminary Review of OECD Test Guidelines for their Applicability to Manufactured Nanomaterials (2009)*

No. 16, *Manufactured Nanomaterials: Work Programme 2009-2012 (2009)*

No. 17, *Current Development/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 5th Meeting of the Working Party on Manufactured Nanomaterials (2009)*

No. 18, *Manufactured Nanomaterials: Roadmap for Activities during 2009 and 2010 (2009)*

No. 19, *Analysis of Information Gathering Initiative on Manufactured Nanomaterials (2009)*

No. 20, *Current Development/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 6th Meeting of the Working Party on Manufactured Nanomaterials (2010)*

No. 21, *Report of the Workshop on Risk Assessment of Manufactured Nanomaterials in a Regulatory Context (2010)*

No. 22, *OECD Programme on the Safety of Manufactured Nanomaterials 2009-2012: Operational Plans of the Projects (2010)*

No. 23, *Report of the Questionnaire on Regulatory Regimes for Manufactured Nanomaterials (2010)*

No. 24, *Preliminary Guidance Notes on Sample Preparation and Dosimetry for the Safety Testing of Manufactured Nanomaterials (2010)*

No. 25, *Guidance Manual for the Testing of Manufactured Nanomaterials: OECD Sponsorship Programme: First Revision (2010)*

No. 26, *Current Development/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 7th Meeting of the Working Party on Manufactured Nanomaterials (2010)*

No. 27, *List of Manufactured Nanomaterials and List of Endpoints for Phase One of the Sponsorship Programme for the Testing Manufactured Nanomaterials: Revised (2010)*

No. 28, *Compilation and Comparison of Guidelines Related to Exposure to Nanomaterials in Laboratories (2010)*

No. 29, *Current Development/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 8th Meeting of the Working Party on Manufactured Nanomaterials (2011)*

No. 30, *Regulated Nanomaterials: 2006-2009(2011)*

No. 31, *Information Gathering Schemes on Nanomaterials: Lessons Learned and Reported Information (2011)*

No. 32, *National Activities on Life Cycle Assessment of Nanomaterials (2011)*

No. 33, *Important Issues on Risk Assessment of Manufactured Nanomaterials (2012)*

No. 34, *Current Development/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 9th Meeting of the Working Party on Manufactured Nanomaterials (2012)*

No. 35, *Inhalation Toxicity Testing: Expert Meeting on Potential Revisions to OECD Test Guidelines and Guidance Document (2012)*

No. 36, *Guidance on Sample Preparation and Dosimetry for the Safety Testing of Manufactured Nanomaterials (2012)*

No.37, *Current Developments in Delegations on the Safety of Manufactured Nanomaterials - Tour de Table at the 10th Meeting of the WPMN (2012)*

No.38, *Co-Operation on Risk Assessment: Prioritisation of Important Issues on Risk Assessment of Manufactured Nanomaterials - Final Report (2013)*

No. 39, *Environmentally Sustainable Use of Manufactured Nanomaterials - Workshop held on 14 September 2011 in Rome, Italy (2013)*

No. 40, *Ecotoxicology and Environmental Fate of Manufactured Nanomaterials: Test Guidelines (2014)*

No.41, *Report of the OECD Expert meeting on the Physical Chemical Properties of Manufactured Nanomaterials and Test Guidelines (2014)*

No.42, *Report of the questionnaire on regulatory regimes for manufactured nanomaterials 2010-2011 (2014)*

No.43, *Genotoxicity of Manufactured Nanomaterials: Report of the OECD expert meeting (2014)*

Nos. 44-54, These items are the dossiers derived from the Testing Programme on Manufactured Nanomaterials which are located at:
http://www.oecd.org/chemicalsafety/nanosafety/testing-programme-manufactured-nanomaterials.htm

No.55, *Harmonized Tiered Approach to Measure and Assess the Potential Exposure to Airbone Emissions of Engineered Nano-objects and their Agglomerates and Aggregates at Workplaces. (2015)*

No.56, *Analysis of the Survey on Available Methods and Models for Assessing Exposure to Manufactured Nanomaterials (2015)*

No.57, *Guidance Manual towards the integration of risk assessment into life cycle assessment of nano-enabled applications (2015)*

No.58, *Preliminary guidance notes on Nanomaterials: Interspecies variability factors in human health risk assessment (2015)*

No.59, *Developments on the safety of manufactured nanomaterials: 2013 (2015)*

No.60, *Current developments in delegations on the safety of manufactured nanomaterials - tour de table (2015)*

No.61, *Developments in delegations on the safety of manufactured nanomaterials - tour de table (2015)*

No.62, *Considerations for using dissolution as a function of surface chemistry to Evaluate environmental behaviour of nanomaterials in risk assessments (2015)*

ABOUT THE OECD

The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation in which representatives of 34 industrialised countries in North and South America, Europe and the Asia and Pacific region, as well as the European Commission, meet to co-ordinate and harmonise policies, discuss issues of mutual concern, and work together to respond to international problems. Most of the OECD's work is carried out by more than 200 specialised committees and working groups composed of member country delegates. Observers from several countries with special status at the OECD, and from interested international organisations, attend many of the OECD's workshops and other meetings. Committees and working groups are served by the OECD Secretariat, located in Paris, France, which is organised into directorates and divisions.

The Environment, Health and Safety Division publishes free-of-charge documents in 11 different series: **Testing and Assessment; Good Laboratory Practice and Compliance Monitoring; Pesticides; Biocides; Risk Management; Harmonisation of Regulatory Oversight in Biotechnology; Safety of Novel Foods and Feeds; Chemical Accidents; Pollutant Release and Transfer Registers; Emission Scenario Documents; and Safety of Manufactured Nanomaterials.** More information about the Environment, Health and Safety Programme and EHS publications is available on the OECD's World Wide Web site (www.oecd.org/chemicalsafety/).

This publication was developed in the IOMC context. The contents do not necessarily reflect the views or stated policies of individual IOMC Participating Organisations.

The Inter-Organisation Programme for the Sound Management of Chemicals (IOMC) was established in 1995 following recommendations made by the 1992 UN Conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The Participating Organisations are FAO, ILO, UNDP, UNEP, UNIDO, UNITAR, WHO, World Bank and OECD. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participating Organisations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

This publication is available electronically, at no charge.

For this and many other Environment, Health and Safety publications, consult the OECD's World Wide Web site (www.oecd.org/chemicalsafety/)

or contact:

OECD Environment Directorate,
Environment, Health and Safety Division
2 rue André-Pascal
75775 Paris Cedex 16
France

Fax: (33-1) 44 30 61 80

E-mail: ehscont@oecd.org

FOREWORD

The OECD Joint Meeting of the Chemicals Committee and Working Party on Chemicals, Pesticides and Biotechnology (the Joint Meeting) held a Special Session on the Potential Implications of Manufactured Nanomaterials for Human Health and Environmental Safety (June 2005). This was the first opportunity for OECD member countries, together with observers and invited experts, to begin to identify human health and environmental safety related aspects of manufactured nanomaterials. The scope of this session was intended to address the chemicals sector.

As a follow-up, the Joint Meeting decided to hold a Workshop on the Safety of Manufactured Nanomaterials in December 2005, in Washington, D.C. The main objective was to determine the "state of the art" for the safety assessment of manufactured nanomaterials with a particular focus on identifying future needs for risk assessment within a regulatory context.

Based on the conclusions and recommendations of the Workshop [ENV/JM/MONO(2006)19] it was recognised as essential to ensure the efficient assessment of manufactured nanomaterials so as to avoid adverse effects from the use of these materials in the short, medium and longer term. With this in mind, the OECD Council established the OECD Working Party on Manufactured Nanomaterials (WPMN) as a subsidiary body of the OECD Chemicals Committee in September 2006. This programme concentrates on human health and environmental safety implications of manufactured nanomaterials (limited mainly to the chemicals sector), and aims to ensure that the approach to hazard, exposure and risk assessment is of a high, science-based, and internationally harmonised standard. This programme promotes international co-operation on the human health and environmental safety of manufactured nanomaterials, and involves the safety testing and risk assessment of manufactured nanomaterials.

This document is published under the responsibility of the Joint Meeting of the Chemicals Committee and Working Party on Chemicals, pesticides and Biotechnology of the OECD.

ACRONYMS

AES	Atomic Emission Spectroscopy
AFM	Atomic Force Microscopy
BET	Brunauer-Emmett-Teller
CLS	Centrifugal Liquid Sedimentation
DLS	Dynamic Light Scattering
DMS	Differential Mobility Spectrometer
EDX/S method	Energy Dispersive X-Ray Spectroscopy
EELS	Electron Energy Loss Spectroscopy
EM	Electron Microscopy
EPM	Electrophoretic mobility
EPR	Electron Paramagnetic Resonance
FFF	Field Flow Fractionation
FFT	Fast Fournier Transform
FT-IR	Fourier Transform Infrared Spectroscopy
GC	Gas Chromatography
HR-TEM	High-Resolution Transmission Electron Microscopy
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
IEP	Isoelectric Point
ISO	International Organization for Standardization
NMR	Nuclear Magnetic Resonance
OECD	Organisation for Economic Co-operation and Development
PZC	Point of Zero Charge
Raman	Raman spectroscopy
ROS	Reactive Oxygen Species
SEM	Scanning Electron Microscopy
SMPS	Scanning Mobility Particle Sizer
TEM	Transmission Electron Microscopy
TGA	Thermogravimetric Analysis
TOF-SIMS	Time-of-Flight Secondary Ion Mass Spectrometry
WPMN	Working Party on Manufactured Nanomaterials
XPS	X-ray Photoelectron Spectroscopy
XRD	X-ray Diffraction

TABLE OF CONTENTS

PHYSICAL- CHEMICAL PROPERTIES OF MANUFACTURED NANOMATERIALS AND TEST GUIDELINES

Background to the OECD series of workshops on manufactured nanomaterials and test guidelines

1. The OECD Working Party on Manufactured Nanomaterials (WPMN) initiated a series of expert meetings to assess the applicability of the OECD Test Guidelines (used for regulatory testing of chemicals) to nanomaterials. A preliminary report was published in 2009[1].

2. The current OECD Test Guidelines (TGs)[2] series address agreed endpoints used for chemical safety assessment, but these TGs are not specifically designed for nanomaterials. It was expected that by reviewing the new findings, experts will be in a better position for evaluating the applicability of current OECD TGs to nanomaterials. On the other hand, if TGs were not applicable, experts may identify the need to update current or develop new test guidelines for those agreed endpoints that are relevant for safety and regulatory decision-making of nanomaterials.

Physical-chemical properties of manufactured nanomaterials

3. The physical-chemical properties and possible exposure pathways are important starting points for risk assessments of chemicals. With this in mind, OECD agreed a number of endpoints to be included in its Sponsorship Programme for the Testing of Manufactured Nanomaterials (hereafter Testing Programme)[3]. Likewise, the OECD publication *Important Issues on Risk Assessment of Manufactured Nanomaterials*[4] stressed that one of the general risk assessment research needs will be the "generation of high quality physicochemical, fate and effects information". As a consequence, OECD decided to further address the relevance of each physical-chemical endpoint for the regulation of nanomaterials.

4. This workshop aimed to discuss the applicability of existing OECD Test Guidelines (TG) on physical-chemical properties of manufactured nanomaterials, and further identify the need to update current or develop new OECD Test Guidelines and/or OECD Guidance Documents (GD) which are relevant for safety and regulatory decision-making of nanomaterials[5].

---

1 Preliminary Review of OECD Test Guidelines for their Applicability to Manufactured Nanomaterials [ENV/JM/MONO(2009)21].

2 http://www.oecd.org/chemicalsafety/testing/

3 i) List of Manufactured Nanomaterials and List of Endpoints for Phase One of the OECD Testing Programme [ENV/JM/MONO(2008)13/REV] and ii) Guidance Manual for the Testing of Manufactured Nanomaterials: OECD Sponsorship Programme: First Revision [ENV/JM/MONO(2009)20/REV].

4 Risk Assessment: Prioritisation of Important Issues on Risk Assessment of Manufactured Nanomaterials - Final Report [ENV/JM/MONO(2012)8].

5 For example, the Guidance manual for the testing of manufactured nanomaterials: OECD's Sponsorship Programme; Preliminary Review of OECD Test Guidelines for their Applicability to Manufactured Nanomaterials, Guidance on sample preparation and dosimetry for the safety testing for manufactured nanomaterials.

Background to the workshop

5. At the 12th meeting of the Working Party on Manufactured Nanomaterials (WPMN) in December 2013, the United States Environmental Protection Agency, with support of the Netherlands National Institute for Public Health, proposed to host an OECD Meeting on Nanomaterials Physical-Chemical Parameters.

6. The OECD WPMN Meeting on Nanomaterials Physical-Chemical Parameters took place the 18-19 June 2014 in Washington DC, USA. This event was hosted by the United States Environmental Protection Agency (US EPA).

7. The main objectives of the meeting were to identify the appropriate test methods for physical-chemical parameters for manufactured nanomaterials, building amongst other things, on the experience from the OECD Testing Programme, the knowledge acquired through the research done by physical-chemical and metrology experts, and if possible, to determine which test methods are appropriate for both a particular parameter and particular types of nanomaterials.

8. This meeting took into consideration the results of the OECD Expert Meeting on the Physical-Chemical Properties of Manufactured Nanomaterials held in Mexico in 2013 and organised in collaboration with the International Organization for Standardization Technical Committee on Nanotechnologies (ISO/TC 229) [ENV/JM/MONO(2014)15].

9. The workshop paid particular attention on the following physical-chemical parameters:

- particle size, shape/aspect ratio, and size distribution;
- aggregation and agglomeration;
- porosity;
- chemical description (including surface composition);
- crystal structure;
- specific surface area;
- surface chemistry;
- surface charge;
- photocatalytic activity;
- zeta potential;
- water solubility/dispersibility;
- dissolution rate/dissolution kinetics; and
- dustiness.

Structure of the workshop

10. The workshop was structured by plenary and breakout sessions aiming at understanding the regulatory challenges, and identifying the issues and value of the different perspectives brought by the experts.

11. Based on the commonly applied risk assessment approaches and current knowledge about possible effects of nanomaterials, the discussions were focused on selected endpoints and those existing OECD Test Guidelines and other methods and protocols that are being used to address them.

12. The categories of endpoints selected were as follows:

- State of dispersion, aggregation and agglomeration of nanomaterials

- Size (and size distribution) of nanoparticles
- Surface area and porosity
- Surface reactivity

13. Consequently, breakout groups were formed with the task to address the following questions:

- Identify the relevance of these endpoints as additions to conventional physical-chemical characterisation; and if relevant, outline possible methods (i.e. new OECD test guidelines) based on the outcomes of the OECD Testing Programme and other sources of information;
- Identify whether there is a need for specific guidance documents for testing and assessment of the physical-chemical properties of nanomaterials or adaptation of existing OECD Guidance Documents;
- Discuss whether specific sections should be developed for the "Guidance on Sample Preparation and Dosimetry" (GSPD) [ENV/JM/MONO(2012)40] on the basis of the experiences obtained in the Testing Programme and other new developments in the area of testing and assessment of physical-chemical properties; and
- Identify whether specific endpoints and/or OECD test guidelines are relevant to different categories of nanomaterials.

OECD expert meeting on the physical-chemical properties of manufactured nanomaterials

Yasir Sultan (Environment Canada, Canada)

14. Yasir Sultan gave a background to the discussions held within the WPMN around physical-chemical properties of nanomaterials for regulatory purposes. Participants were reminded that a workshop around this topic was held in 2013, which benefited from the expertise of ISO TC 229. This exchange between both organisations allowed a better understanding on those aspects of the physical-chemical properties that are more relevant for the regulatory decision making. The *Report of the OECD expert meeting on the physical chemical properties of manufactured nanomaterials and test guidelines* can be downloaded from the OECD http://www.oecd.org/env/nanosafety as ENV/JM/MONO(2014)15 and ENV/JM/MONO(2014)15/ADD.

OECD testing programme[6]: Overview of the assessment of the physical-chemical data

Monique Groenewold (National Institute for Public Health and the Environment (RIVM), The Netherlands)

15. Monique Groenewold reported on the OECD project on the *Assessment of the physical-chemical data from the Testing Programme*, which included data from 11 types of nanomaterials collected by different members of the OECD and assessed for validity. This exercise was led by the Netherlands. Until that moment the data had not yet been assessed, thus an inventory of knowledge and expertise of physical-chemical test methods was made to assess the gaps. It was noted that the majority of the data from the Testing Programme was already available; however, as the collection was still underway, there were some data gaps. In total, 24 different physical-chemical test methods were evaluated, and no OECD guidelines were used. Participants noted that after compaction of the assessment of the physical-chemical data, the

[6] The results from the OECD Testing Programme are available at: http://www.oecd.org/chemicalsafety/nanosafety/testing-programme-manufactured-nanomaterials.htm

WPMN will continue with the remaining parameters on human health and on the ecotoxicity addressed through the Testing Programme.

Physical-chemical characterisation of engineered nanoparticles: The measurands that influence nano EHS / Activities of the ISO Technical Committee 229

Shaun Clancy (Evonik Corporation, BIAC)

16. Shaun Clancy gave a presentation of ISO activities regarding measurement methods to probe the interface of nano-objects. He explained the structure of ISO Technical Committee on Nanotechnology (ISO TC229); as well as role of the working groups focused on "Health Safety and Environment" and "Measurement and Characterization". More than 30 projects are implemented by task groups focusing on each issue. He also introduced several projects and reported the latest activities in ISO TC 229.

PHYSICAL IDENTIFICATION

Chair: Hubert Rauscher (Joint Research Centre (JRC), European Commission)
Rapporteur: Eric Grulke (University of Kentucky, United States)

17. This session discussed the following parameters supporting the physical identification of nanoparticles:

- Particle size and particle size distribution
- Particle shape/Aspect ratio
- Aggregation/Agglomeration states
- Porosity and Specific Surface Area

Particle size distribution

18. Participants agreed on a number of aspects that needed to be clarified before the discussion. For example, there is a need to clearly articulate the purpose for which the particle size distribution will be used:

- Research – what information do we need?; which method(s) will give us this?
- Standards – are the techniques consistent, well known?; what is the availability?; is normative work available?
- Regulation – [OECD test guidelines] do the measurements link to 'real world' reality?; what do regulators need for size and size distribution + levels of uncertainty?; are the mean and the breadth of the distribution important?; are measurement uncertainties or additional statistics important?; [this would be essential for comparison of distributions, rather than comparison of means]

19. Sampling and sample preparation will dictate appropriate particle size and particle size distribution methods, i.e., changes in either of these can make large differences in the reported measurements. In addition, particle dispersion methods are essential to understanding size and size distribution data.

20. In general, complementary methods should be used to confirm results since particle size methods are very method-dependent. For example, different weighting or Transmission electron microscopy (TEM) (which cannot image carbonaceous matter well; or which image can also be affected by image analysis software).

21. Standard operating procedures (SOPs) are valid when linked to specific protocols. All particle size and particle size distribution methods should be calibrated with standard materials.

22. The selection of the appropriate techniques for particle size and particle size distributions would be aided by a decision tree analysis. It was noted that there are some publications that start to define such a framework.

Specific analysis of particle size measurement methods

23. The table was prepared by participants to summarise comments relate to the evaluation of some of the methodologies.

Methods considered during the discussion	**Advantages; appropriate apps**	**Disadvantages**	**Regulatory; research**
Particle size			
	Sampling, sample prep will dictate appropriate methods		
TEM	Dry powder; experts must define the preferred sample preparation for the results that are needed ; EDX/S method is very valuable (combination of image + material analysis); cryo-TEM (for which samples)	2-D image, sampling bias; sample should be representative; sample prep, image analysis; what is individual and what is agglomerated, aggregated?; sampling issues and basis; aberration effects, lenses are not perfect	Expensive for regulatory purposes, not always available; cost factor; best practice for regulatory may be different than that for research; information needs to be germane to regulatory needs; appropriate for very small particles; HR-TEM for particles with physical boundaries; simulate 3D via rotation (research)
SEM	Dry powder; valuable for larger particles; rapid; available;	May not have the resolution needed; type of material?	Regulatory: sufficient resolution for a number of materials; difficult to have statistical accounting of "wings" of the distribution (any EM); how many do we need to count?; supply source
DLS	Hydrodynamic diameter; measuring 10^5 + particles; inexpensive; good for narrow distributions;	Variable relation to TEM image; non-spheroidal particles may need corrections; less distribution information (1 angle instruments, intensity-weighted); depends on viscosity and refractive index of media (and particle)	Intensity-, number-, volume-, surface- average?; platelets, rods, disks need significant corrections; degree of correction is affected by aspect ratio (AR>>1 is an issue); what do we want? – diffusion coefficient along either axis, …
CLS	Very rapid; liquid dispersions; density of particles; good resolution and can detect minority components; state of aggregation is measured	Poor signal-to-noise ratio in some cases when the technique is not tuned properly (low loading of silica for example) – true for all these techniques; does not distinguish individual particles and cannot (always) identify aggregates.	

24. The following three elements such as "shape and aspect ratio", "agglomeration/aggregation" and "porosity specific surface area" were discussed in a small group setting.

Shape and aspect ratio

25. Experts recognised these parameters as relevant. To describe *shape and aspect ratio*, experts identified the guidance by the European Chemical Industry, which is based on ISO standard 9276-6:2008 as applications (classification tree) and ISO/TS 27687: 2008 as definitions. As for ISO 9276-6: 2008, it was noted that the parameters are linked to image analysis and if the shape is known then better information can be obtain from CLS, DLS.

26. The need was also noted to differentiate information on the smallest dispersible unit or the primary particle (surface reactivity) for the issue of "primary particles versus aggregates".

27. Regarding the measurement, experts recommended the use of ISO definitions for shape descriptors (i.e., ISO 9276-6:2008). It was also suggested to develop guidance on when to apply which shape descriptors and how they link to nanoparticle performance, as well as what details might be important. The following examples were given:

- Link surface plasmon resonance to elliptical parameters
- Aspect ratio as a shape descriptor – oblate or prolate ellipsoid; nanorod,
- Not all shape factors might be linked to regulatory needs
- Disk, rod, spheroidal – link to ISO 27687; based on an image (EM, AFM, light microscopy by advanced fluorescence methods as examples)

28. In addition, shape factors might be subsumed in EM technical specifications for size, and size distributions of "rough" particles.

Agglomeration/aggregation

29. In the EU definition, aggregation is a tightly bound collection of particles and agglomeration is a loosely bound collection of particles. ISO 27687 provides a definition of them. On the other hand, it should be considered what the quantitative definitions of these are and the difference between the size distribution of aggregates and the one of non-aggregates.

30. From the regulatory point of view, aggregate vs. agglomerate were seen as important, and agglomeration and aggregation are *in situ* states.

31. Regarding the *measurand*, there was a question whether there are examples we need about agglomeration and aggregation 'state':

- The number of primary particles in an aggregate;
- The number of aggregates compared to the number of non-aggregated
- Multiple methods for defining fractional aggregation, agglomeration.
- Size distribution of these: mean, shape factor of the distribution
- Size distribution after dispersion protocol
- *In situ* measurement of size distribution
- Surface area particle size distribution

32. To assess the need for a test guideline on aggregation, it was first suggested to evaluate TR 13097:2013. In addition, attention should be paid to 'safer by design' when a material aggregated: for example, titanium aggregates when it leaves paint.

Porosity specific surface area

33. BET gas adsorption model breaks down at small pores sizes, which are, for example, less than 2 nm and correction may be based on the material. For non-porous particles, BET can be used to get external surface area of non-porous particles. On the other hand, for porous particles, BET would detect both internal pores and external surface area; for some samples, internal porosity can overwhelm external surface area. Therefore, special attention will need to be drawn on how to address this, as well as how to differentiate between internal pores and external surface area.

34. Finally, it was suggested to assess ISO 18757:2003; BS IOS 9277:2010; ASTM B922-10 to determine whether they are applicable to nanoparticles and/or nanoparticles with porosity.

CHEMICAL IDENTIFICATION OF NANOPARTICLES: PARAMETERS

Chair: Eric Bleeker (National Institute for Public Health and the Environment, The Netherlands)
Rapporteur: Shaun Clancy (Evonik Corporation, BIAC)

35. This session was focused on "chemical composition", including surface composition, and "crystallinity and crystal structure".

Chemical composition

Core composition

36. Based on the preliminary review of the physical-chemical data from the OECD Testing programme, it was reported that ICP-OES is a valid method for SiO_2 and EDX is valid for SiO_2 and Ag. For CNTs the list of valid methods includes TGA, BET, TEM/SEM, XPS, FT-IR and Raman.

Surface composition

37. Methods considered to be valid include TGA, BET, TEM/SEM (w/EDX), XPS, FT-IR (for functional group determination), Raman (to determine structure), and ICP (to determine metals on the particle surface).

38. Regarding the needs from regulators, the following points were expressed:

- Regulators would prefer a short set of tests that can be recommended when preparing regulatory submissions;
- The list would not necessarily be the same for all nanomaterials or classes of nanomaterials and could be based on what regulators want to know. For example, for nanotubes, a metric for stiffness may be important, whereas for quantum dots photoactivity could be more relevant.
- Regulators need information that will allow an effective review of the dossier. For example, the intended composition, and by-products and impurities.
- What methods can be ID surface elements that may be reactive in the body? For example, can the presence of –OH, -CHO, or –COOH be distinguished if a CNT is oxidised?
- Submitters would like a consistent set of requirements/methods so that the information generated to support a submission will be generally applicable to meet regulatory needs around the world.
- While there is a focus within the experts on laws/regulators pertaining to industrial chemicals such as CEPA, REACH, NICNAS, TSCA, industry also has to address potential regulatory requirements under other laws/reg. Examples include pesticides (FIFRA/PMRA/Biocides Directive); food, drug & cosmetics (FFDCA/FDA, EU Food Regulations, pharmacopeia, Cosmetics Directive); and hazard communication (SDS, hazardous substances lists, etc.). It was suggested that a guidance document (e.g. for CNTs) could be developed and include the type of methods to use by endpoints.

39. A list of methods applicable to CNTs was identified: TGA, BET, TEM/SEM, XPS, FTIR, Raman, ICP, XRD, Headspace GC. It was observed that the techniques in the list appear to be not very expensive which is very important to SMEs. Follow up questions/observations included:

  - Could such a list be generalised for its use to other materials?
  - Can a decision-tree be developed to direct their use? (Comment – probably not)

- When exposed to media additional characterisation may be needed to address changes in properties using the same list.
- Limits of detection may need to be considered.
- Can guidance be developed to understand when each method can be considered? E.g. for surface functionality, EM may not be useful.
- What about the durability of surface coatings (full surface coverage) or surface treatments (partial surface coverage)?
- Solid-state NMR was noted as a method that should not be considered routinely.

Crystallinity/Crystal structure

40. The property of crystallinity may not apply to all materials but for those where it can be applied it is important. For titanium, the differences between rutile vs. anatase, as well as between amorphous vs. crystalline silica were noted. Crystallinity is generally important and provides information about the presence of defects, amorphous vs. ordered, solubility, reactivity, surface charge, etc. It may be possible to establish a hierarchy for some types of materials. For example, for carbon materials crystallinity is essential (also surface chemical, rigidity, the number of walls for CNTs).

41. Crystallinity is a manifestation of molecular structure and can be a proxy for other properties such as surface chemistry, solubility, among others. Because of the possible relationship between crystallinity and chemistry, bulk crystallinity and surface chemistry should be considered together. For some materials (e.g. CeO_2 <10 nm) the relationship is blurred. Hybrid materials can be challenging with example including core-shell, mixed structures (anatase/rutile), and catalyst-islands. Geometric factors may need to be considered.

42. The needs of regulators were identified as follows:

- Chemical identity, surface structure, certain properties. May inform read-across. There is a need for regulators to have information that helps them better understand new materials and their properties. A decision-tree would be useful.
- Crystallinity is important for identification. For risk assessment information on surface chemistry is more critical.
- With respect to specific methods, it was noted:
  - Determination of surface chemistry which may be related to surface crystallinity is difficult and "standard" methods for bulk crystalline properties do not necessarily work. The degree of resolution needed has to be considered. Appropriate methods include TOF-SIMS, XPS, AES, EELS (for surface chemical).
  - FFT needs to be removed as a method. Fast Fourier Transform is a mathematical method that is applicable to a variety of individual methods.

SURFACE PROPERTIES

Chair: Scott Brown (DuPont Central Research & Development BIAC)
Rapporteur: Greg Smallwood (National Research Council Canada, Canada)

Surface charge

43. Participants refer to results on the literature reviews (Brown SC, et al. 2010; Bucher, J., et al. 2004; Powers KW et al. 2006) and agreed to recommend that:

- Report the IEP using a simple background electrolyte and water;
- Report the zeta potential at the pH intended to be used for the given test system; identify model used; and
- Report the zeta potential in the test medium; identify model used and raw mobility data [electric mobility].

44. Regarding the data generated through the OECD Testing Programme, it was noted that in many cases the IEP was not given, the model applied (e.g., Smoluchowski) was not identified, and that reference values in a pure system were not always provided. It was also concluded that the point of zero charge (PZC) is a useful parameter to assess the surface acidity of CNTs, usually performed by mass titration.

45. Zeta potential is the measurement of electrostatic interactions between dispersed particles. Electrophoretic mobility (EPM) is measured by a zeta potential analyser, and then EPM is converted to zeta potential based on Smoluchowski's Approximation. Many studies have indicated CNTs to be negatively charged regardless of synthesis methods. It should be noted that the formula used for estimation of zeta potential has been developed for spherical materials, so the approximation may be overestimate zeta potential of non-spherical materials.

46. Special attention was drawn to existing standards such as:

- ISO 13099-1:2012 Colloidal systems — Methods for zeta-potential determination — Part 1: Electroacoustic and electrokinetic phenomena
- ISO 13099-2:2012 Colloidal systems — Methods for zeta-potential determination — Part 2: Optical methods
- ISO 14887:2000 Sample preparation — Dispersing procedures for powders in liquids

47. And it was mention that other existing methods from US EPA and ASTM methods should also be explored.

Surface charge (methods)

48. The group considered optical electrophoresis, electroacoustics, and Doppler shift (micro) electrophoresis. It was noted that similar results achieved for instruments representing each of the three

methods. Most seem to use Doppler shift electrophoresis although there was a slight preference in recommending electroacoustics. OECD has nothing that is prescriptive in terms of specific method. Finally, there is no specific recommendation on the surface pKa; only a complementary measurement to methods such as optical electrophoresis, electroacoustics, and Doppler shift (micro) electrophoresis.

Photocatalysis

49. A number of methods exist in the literature regarding the photocatalysis and there are existing standards as follows:

- DIN 52980:2008-10 (Methylene Blue Assay);
- ISO 22197-2 C or JIS R1701-2(Acetaldehyde degree);and
- ISO 10676 (2010), ISO 10678 (2010) (Methylene Blue, and DMSO).

50. It was concluded that all the methods mentioned above are to be considered screening methods for photoactive materials. They are not suitable for quantitative/normative measurements. An option could be to identify/compare/quantify radical type generated by photoactive materials.

51. It is also needed to consider several elements such as solubility, size, adsorption, agglomeration in a decision tree prior to making a photocatalysis assay. We also need to discuss whether we should make a saturated solution in order to measure photocatalysis. In addition, it may need reference materials that are fit-for-purpose.

Surface reactivity

52. While there is a wide range of tests in the literature, some endpoints are specific and others are more general (e.g., degradation). For example, for specific assays, there are ROS, and fluorescence and EPR whereas quantum effects in fluorescence for small nanoparticles exist. It is necessary to be concerned about opacity of solution, in addition to colouring. The Vitamin C Assay is used for general assays.

53. The surface reactivity might be needed as a screening test, for example in a second tier, after surface composition is known.

54. Surface is designed, capped, treated to meet specific application requirements by manufacturer, and not left to chance. It is not likely to be unknown for engineered nanomaterials; tests are not likely to be prescribed.

55. While there is no current recommendation on needs for surface reactivity, there may be needs for surface reactivity techniques in the future, but a broad spectrum of possible techniques exists depending on specific nanomaterial and application/endpoint (these need information on surface composition and chemical structures).

56. Surface reactivity was recognised as a diverse endpoint. Regulators need to clearly identify questions and methods to answer those questions (i.e. reactive in oxygen, in water, in nitrogen, etc.). A separate discussion could take place to further narrow the discussion on exposure/biological effects.

PARAMETERS RELEVANT FOR FATE AND EXPOSURE

Chair: Pat Rasmussen (Health Canada, Canada)
Rapporteur: Vince Hackley (National Institute of Standards and Technology (NIST), United States)

57. The parameters relevant for fate and exposure determination of nanoparticles that were addressed were: "zeta potential", "water solubility/dispersibility/dissolution rate and dissolution kinetics", and "dustiness".

Zeta potential

58. It was noted that the Laser Doppler Electrophoresis is the method used within the OECD Testing Programme. ISO standards as well as some protocols exist (e.g., NIST/NCI protocol PCC-2).

59. Electrophoretic mobility is unambiguous and should be reported along with the zeta potential and the method/equation used to calculate zeta potential from EM (e.g., Smoluchowsi, Henry, etc.). In addition, the isoelectric point would provide useful additional information (i.e., zeta potential vs. pH curve – point of zero zeta potential).

60. It was suggested to refer to the OECD *Guidance on Sample Preparation and Dosimetry for the Safety Testing of Manufactured Nanomaterials* [ENV/JM/MONO(2012)40]. In addition, recommended examining ISO standard guide for zeta potential measurement by light scattering electrophoresis; depending on results of this examination, there might be a need for further guidance specific to nanomaterials and regulatory needs.

Water solubility/Dispersibility/Dissolution kinetics

61. The group acknowledged a number of activities completed or underway that could already address the regulatory needs in this area, such as: i) the review of the OECD Test Guideline 105 (solubility) and the OECD Guidance Document 23 on Aquatic Toxicity Testing of Difficult Substances and Mixtures (includes dispersions and emulsions) for their applicability to nanomaterials; ii) South Africa's work on biodurability under OECD and ISO; iii) OECD work on dissolution of metals for aquatic toxicity and also on dispersibility/stability; iv) as well as other activities in other forums such as ILSI.

62. Participants recognised the value in getting general guidelines for measurements relevant to human health/exposure. Also, the need was identified to consider specific conditions in human systems (e.g., gastric, pulmonary and lysosomal); while guidance for application/execution of dissolution studies could be found in ecotoxicity/aquatic studies.

63. Regarding water solubility, dispersibility, and /dissolution kinetics, the group suggested to wait for the results of the OECD activities on aquatic ecotoxicity. In addition, it was suggested to review published literature in relation to human systems.

Dustiness

64. The main problem identified was the reproducibility of aerosol generation, not the measurement of aerosols. Important aspect is defining dustiness with respect to occupational exposure and mitigation measures. The collection of data on a wide range of materials from the Danish National Research Institute for the Working Environment was mentioned as a useful reference. The group also concluded that sub-100 nm particles could not be generated. A NIOSH study published in 2013 also concluded no modes below 100 nm after looking at 27 fine and nanoscale powders. There is standard BS EN 15051:2006 which is based on two methods: i) rotating drum; and ii) continuous drop method.[7]

[7] There is also the document ISO/TS 12025:2012 "Nanomaterials -- Quantification of nano-object release from powders by generation of aerosols", which describes dustiness methods including the Vortex shaker method and Dynamic method as well as Rotating drum and continuous drop methods (see Section 6.4.1). Furthermore, the OECD Guidance on Sample Preparation and Dosimetry for the Safety Testing of Manufactured Nanomaterials [ENV/JM/MONO(2012)40] also includes descriptions regarding dustiness testing (see section A.1.12).

RECOMMENDATIONS

65. Participants recognised the value of an OECD guideline for mitigating exposure, but there is first a need to harmonise methods and control of conditions of measurement.

66. The concluding recommendations on the methods and techniques for particle size, distribution, and shape of manufactured nanomaterials were as follows:

- A decision tree needs to be developed for particle size. This decision tree will need to take into account how the information will be used (e.g., for identification, exposure, etc. – this will also inform sample preparation). This decision tree should consider relevant literature on methodical correlations[8]. For identification purposes, the group considered as a good starting point to use electron microscopy (TEM/SEM[9]), and when not appropriate, consider inferred size methods (such as DLS, CLS (hydrodynamic) and SMPS, DMS (mobility).

- Technical guidance is needed on the application of electron microscopy (EM) for determining the size and size distribution and shape of particulate materials. This technical guidance will need to take into account how the information will be used. EM is often, but not always, the benchmark method for median particle size and the estimate of particle size distribution (number based) for nanomaterial identification (uncertainty will improve with method development; tandem methods should also be considered for validation);

- Guidance needs to be developed in tandem to the decision tree on dispersion protocols, while considering defining smallest dispersible size. All methods in the decision tree should be accompanied by detailed dispersion protocols (minimum set of descriptors are needed). Dispersion state is not well characterised by EM and instead should be determined by suspension based methods (CLS, FFF, DLS, etc.).

67. For all the physical-chemical properties discussed, the group saw:

- The need to identify the appropriateness of techniques/methodologies for specific measurands for different nanomaterial chemical/structural-based categories. These categories should not pre-judge the appropriateness of read-across for hazard properties. This recommendation is to focus on what we are looking at (e.g. CNTs, metal oxides, elemental metals, quantum dots, others).

- Develop a guidance document based on the chemical identification descriptors/behaviours needed leading to selection of techniques/methodologies. Prioritise how to select the order of each descriptor and identify available techniques/methodologies. Determine if available information (including literature references) is adequate and if not what additional information is needed.

[8] For example, the paper by Wohlleben et. al . (Jo. Ceramic Sci 2013 and EHP 2013).

[9] The group noted that TEM/SEM is not suitable for measuring in liquids (unless a "liquid cell" is used). For air a different method is needed.

[Consider paper by Pettitt, Lead, et al referenced in Thought-Starter]. This recommendation is to focus on the material we have and the parameter we need (surface area, size distribution, agglomerates, porosity, morphology, and purity);

- Develop guidance on available methods for chemical composition, giving consideration to functional tests when appropriate; and

- Develop guidance on how to determine crystallinity, where results for the bulk are not sufficient, focusing on which methods to use when (what to use for CNTs, what to use for very small particles), including how to deal with surface crystallinity.

REFERENCES

Brown SC, et al. (2010) Nanoparticle characterization for cancer nanotechnology and other biological applications. Methods Mol Biol 624:39-65.

BS EN 15051:2006 Workplace atmospheres: Measurement of the dustiness of bulk materials. Requirements and reference test methods\.

Bucher, J., et al. (2004) Developing Experimental Approaches for the Evaluation of Toxicological Interactions of Nanoscale Materials. Final Workshop Report3 –4 November, 2004, 1–37; University of Florida, Gainesville, FL.

OECD, 2012. Guidance on Sample Preparation and Dosimetry for the Safety Testing of Manufactured Nanomaterials [ENV/JM/MONO(2012)40].

Pettitt, M.E. et al. (2013) Minimum physicochemical characterization requirements for nanomaterial regulation. Environment International 52 (2013) 41-50.

Powers KW et al. (2006) Research strategies for safety evaluation of nanomaterials. Part vi. Characterization of nanoscale particles for toxicological evaluation. Toxicological sciences 90:296-303.

Wohlleben W., et al. (2013) Nanospecific Guidance in REACH: A Comparative Physical-Chemical Characterization of 15 Materials with Methodical Correlations. Journal of Ceramic Science and Technology Vol.4, No.2, Pages 93-104.

PARTICIPANT LIST

OECD Meeting on Nanomaterials Physical-Chemical Parameters: Measurement and Methods Methods

Washington , United States

18/6/2014 - 19/6/2014

Canada

Dr. Linda JOHNSTON
Team Leader, Nanoscale Measurement
Measurement Science for Emerging Technologies
National Research Council Canada
100 Sussex Drive,
K1A 0R6 Ottawa
Canada

Dr. Gregory J. SMALLWOOD
Program Lead, Measurement Science for Emerging Technologies
Measurement Science and Standards
National Research Council Canada
1200 Montreal Road, Building M-9
K1A 0R6 Ottawa
Canada

Ms. Myriam HILL
Head, Nanotechnology Section
CEPA New Substances Assessment Division
Health Canada
New Substances Assessment and Control Bureau HECS
99 Metcalfe Street
K1A 0K9 Ottawa
Canada

Dr. Pat RASMUSSEN
Researcher
Exposure and Biomonitoring Division
Health Canada
Environmental health Science and Research Bureau
50 Colombine Driveway,
Tunney's Pasture,
Room 209,
K1A 0K9 Ottawa
Canada

Dr. Yasir SULTAN
Senior Science Advisor, Nanotechnology Section
Emerging Priorities Division
Environment Canada
Science and Technology Branch
351 Boulevard St-Joseph,
J8Y 3Z5 Gatineau
Canada

France

Dr. Nicolas FELTIN
Responsable de Mission en Nanométrologie Pôle de Recherche en Métrologie Avancée Direction DMSI
Laboratoire national de métrologie et d'essais
29, Avenue Roger Hennequin
78197 Trappes
France

Germany/Allemagne

Dr. Harald JUNGNICKEL
Federal Institute for Risk Assessment (BfR)
Max-Dohrn-Str. 8-10
10589 Berlin
Germany

Ms. Carmen NICKEL
Dipl. Environmental Scientist
Institute of Energy and Environmental Technology e.V. (IUTA)
Bliersheimer Str. 60
47229 Duisburg
Germany

Japan/Japon

Dr. Kazuhiro YAMAMOTO
Chief Senior Researcher
Research Institute of Instrumentation Frontier
National Institute of Advanced Industrial Science and Technology (AIST)
Tsukuba Central 2, Umezono 1-1-1, Tsukuba
305-8568 Ibaraki
Japan

Mr. Masashi HORIE
Staff
Office of the Data Preparation for Risk Analysis, Risk Analysis Division, Chemical Management Center
National Institution of Technology and Evaluation (NITE)
2-49-10, Nishihara, Shibuya-ku
151-0066 Tokyo
Japan

Mr. Hitoshi MORISHITA
Principal Researcher
JFE Techno-Research Co.
7-1 Otemachi 2-chome, Chiyoda-ku
100-0004 Tokyo
Japan

Mr. Yoshisato KIYOTA
Senior Researcher
Business Consulting Division
JFE Techno-Research Co.
7-1,Otemachi 2-chome, Chiyoda-ku
100-0004 Tokyo
Japan

Korea/Corée

Professor Young Hun KIM
Professor
Chemical Engineering
Kwangwoon University
506 Hwado Building, Dep. Chem. Eng. Kwangwoon Univ.
Wolgey-dong Nowon-gu Seoul Korea
Seoul
Korea

Netherlands/Pays-Bas

Dr. Gerhard BLAB
Debye Institute for Nanomaterials Science
Utrecht University
P.O. Box 80.000
3508 TA Utrecht
Netherlands

Dr. Eric BLEEKER
Centre for Safety of Substances and Products
National Institute of Public Health and the Environment (RIVM)
P O BOX 1
NL-3720BA Bilthoven
Netherlands

Mrs. Monique GROENEWOLD
Coordinator KIR-nano
Expertise Centre for Substances (RIVM-SEC)
National Institute of Public Health and the Environment (RIVM)
P O BOX 1
NL-3720BA Bilthoven
Netherlands

Turkey/Turquie

Mr. Cem ERDOGAN
Physiology and Toxicology
MINISTRY OF FOOD AGRICULTURE AND LIVESTOCK TURKEY
Gayret mahallesi Fatih Sultan Mehmet Bulvari, No: 66
06172 Ankara
Turkey

Dr. Suat KAYMAK
Director
MINISTRY OF FOOD AGRICULTURE AND LIVESTOCK TURKEY
Plant Protection Central Research Institute Gayret Mah. FSM Blv. No.66
Yenimahalle
06172 Ankara
Turkey

United States/États-Unis

Dr. Souhail AL-ABED
National Risk Management Research Laboratory
U.S. Environmental Protection Agency (EPA)
Office of Research and Development
26 W. Martin Luther King Dr.
Mail Code CHL
45268 Cincinnati
United States

Dr. William BOYES
National Program Director
National Health and Environmental Effects Research Laboratory
US Environmental Protection Agency
Office of Research and Development
109 T.W. Alexander Drive
Mail Code: B105-04
27711 Research Triangle Park
United States

Dr. Maria DOA
Director
Chemical Control Division
U.S. Environmental Protection Agency (EPA)
Office of Chemical Safety and Pollution Prevention
1200 Pennsylvania Ave., NW
Mail Code 7405M
20460 Washington
United States

Dr. Richard FEHIR
U.S. Environmental Protection Agency (EPA)
Office of Chemical Safety and Pollution Prevention
1200 Pennsylvania Ave., NW
Mail Code 7406M
20460 Washington
United States

Dr. Eric GRULKE
Associate Dean
Research and Graduate Studies Chemical & Materials Engineering
University of Kentucky
Chemical & Materials Engineering
763H F Paul Anderson Tower
University of Kentucky
KY 40506 Lexington
United States

Dr. Vincent A. HACKLEY
Research Chemist
Nanoparticle Measurements & Standards (Project Leader)
National Institute of Standards & Technology
100 Bureau Drive, Stop 8520
20899-8520 Gaithersburg
United States

	Ms. Debra KAISER Chief, Ceramics Division NIST 100 Bureau Drive, Stop 8520 20899 Gaithersburg
	Dr. Doyoung LEE Senior Chemist Office of Pollution Prevention and Toxics U.S. Environmental Protection Agency 1200 Pennsylvania Ave., NW (7406M) 20460 Washington United States
	Dr. Kim ROGERS National Health and Environmental Effects Research Laboratory US Environmental Protection Agency Neurotoxicology Branch Office of Research and Development 109 T.W. Alexander Drive Mail Code: D205-05 Research Triangle Park NC 27709 RTP United States
EU/UE	Mr. Hubert RAUSCHER JRC JRC - Institute for Health and Consumer Protection (IHCP) Via E. Fermi 2749 T.P. 202 21027 ISPRA Italy
	Mr. Abdelqader SUMREIN Junior Scientific Officer Directorate of Evaluation European Chemicals Agency (ECHA) Annankatu 18, P.O. Box 400, FI-00121 Helsinki Finland
Business and Industry Advisory Committee (BIAC)/Comité consultatif économique et industriel (BIAC)	Dr. Scott BROWN Senior Research Scientist DuPont's Corporate Center for Analytical Sciences' Particle and Surface Science competency The Chemours Company

DuPont Experimental Station 323/110A
1007 Market Street
19899 Wilmington
United States

Dr. Shaun CLANCY
Director - Product Regulatory Services
Evonik Corporation, 299 Jefferson Road, Parsippany, NJ 07054, USA
299 Jefferson Road
07054 Parsippany
United States

Dr. Yoshihito DEGUCHI
Sumitomo Chemical America Inc.
150 East 42nd Street
Suite 701
10017 New York
United States

Dr. Steffi FRIEDRICHS
Director General
Nanotechnology Industries Association
143 Avenue de Tervuren
1150 Woluwe-Saint-Pierre
Brussels
Belgium

Dr. Lawrence MURPHY
R&D Director - Analytical Sciences/Laboratories
Research and Development
Cabot Corporation
157 Concord Road
01730 Billerica
United States

Dr. Martin REISINGER
Evonik Industries AG
Rodenbacher Chaussee 4
63457 Hanau
Germany

Dr. Wendel WOHLLEBEN
Material Physics
BASF SE
GMC/R - G201
67056 Ludwigshafen
Germany

Mr. Koichi YANASE
Japan Chemical Industry Association
Sumitomo Rokko BLDG. 1-4-1 Shinkawa, Chuo-ku Tokyo
104-0033
Japan

International Council on Animal Protection in OECD Programmes

Dr. Amy CLIPPINGER,
Science Advisor
Regulatory Testing Division
People for the Ethical Treatment of Animals
501 Front St.
23510 Norfolk
United States

OECD/OCDE

Ms. Mar GONZALEZ
Administrator, Nanosafety, Chemical Accidents, and Outreach
ENV/EHS
OECD
Marshall Building 0295
2 rue André-Pascal
75016 Paris
France