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**ENVIRONMENT DIRECTORATE  
CHEMICALS AND BIOTECHNOLOGY COMMITTEE**

**Developments in Delegations on the Safety of Manufactured Nanomaterials and  
Advanced Materials – Tour de Table**

**July 2024 – June 2025**

This document compiles information, provided by delegations on current developments on the safety of manufactured nanomaterials (July 2024 – June 2025).

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# About the OECD

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The Environment, Health and Safety Division publishes free-of-charge documents in twelve 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; Safety of Manufactured Nanomaterials; and Adverse Outcome Pathways.** More information about the Environment, Health and Safety Programme and EHS publications is available on the OECD's World Wide Web site (<https://www.oecd.org/en/topics/chemical-safety-and-biosafety.html>).

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

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, Basel, Rotterdam and Stockholm Conventions 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.

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# 1 National developments on human health and environmental safety

## 1.1 Austria

### 1.1.1 NanoTrust-Beyond

The long-term nano risk governance project *NanoTrust*, hosted and managed by the Institute of Technology Assessment (ITA) at the Austrian Academy of Sciences (OeAW), has been initiated in 2007 and continues as *NanoTrust-Beyond* (its seventh iteration) until 2027 ([oeaw.ac.at/en/ita/nanotrust](https://oeaw.ac.at/en/ita/nanotrust)). The main task of the project is to continuously monitor, analyse, and summarise the state of knowledge regarding potential health and environmental risks of nanotechnology. Following the retirement of the previous project manager André Gzásó at the end of 2024, *NanoTrust-Beyond* underwent significant personnel changes at the beginning of 2025. Two experts in engineering, social, and natural sciences have assumed primary responsibility for the project (Gudrun Lettner, Jean Schmitt).

Within the framework of the Austrian Nano EHS program, the *NanoTrust-Beyond* team hosted an event at the OeAW in February 2025, in which the new Nano EHS status report<sup>1</sup> as well as submission from the Austrian research community were discussed. The status report details a total of 144 ongoing projects funded by both EU and national sources (currently restricted to the Germany-Austria-Suisse region), encompassing ten thematic clusters. Experts' feedback on future relevant issues and topics was gathered through qualitative interviews, subsequently analysed, and categorized into thematic clusters. On this basis, the Nano-EHS steering group discussed the topics for the next Austrian EHS call.

*NanoTrust-Beyond* continued elaborating and publishing so-called *NanoTrust-Dossiers*. These briefs (approx. six pages) are available in German and English online: [oeaw.ac.at/ita/publikationen/publikationsreihen/na-notrust-dossiers](https://oeaw.ac.at/ita/publikationen/publikationsreihen/na-notrust-dossiers) and [oeaw.ac.at/en/ita/publications/publication-series/nanotrust-dossiers](https://oeaw.ac.at/en/ita/publications/publication-series/nanotrust-dossiers).

In the last quarter of 2024, NanoTrust Dossiers were published focusing on ceramic dental implants<sup>2</sup>, on the *Safe and Sustainable by Design* (SSbD) concept in the context of the development of safe and

<sup>1</sup> Lettner, G., Schmitt, J., Bettin, S. & Gzásó, A. (2025). *Statusbericht 2025 Nanotechnologie, Environment, Health & Safety Projekte; Nr. 2025-02, epub.oeaw.ac.at/ita/ita-projektberichte/ITA-2025-02.pdf*.

<sup>2</sup> Breitwieser, A., Pavlicek, A., Part, F., Koppler, M., Zäuner, M., Ehmoser, E. -K., & Gzásó, A. (2024). *Zahnimplantate aus Keramik (NanoTrust-Dossier Nr. 063 – Juni 2024)* (p. 7). Wien. [doi:/10.1553/ita-nt-063](https://doi.org/10.1553/ita-nt-063)

sustainable chemicals and materials<sup>3</sup>, and on the ecotoxicological risks of nano- and microplastics<sup>4</sup>. In spring 2025, three dossiers on Engineered Living Materials will be finalized and published.

The newly formed *NanoTrust-Beyond* team will continue to perform both scientific and advisory functions. Its scientific work will primarily focus on the preparation and coordination of *NanoTrust Dossiers* and to reflect the developments in the field of nanomaterials and advanced materials. In terms of content, the initial focus will lie on two key areas: sustainability and social responsibility, on the one hand, and international standardization activities in the field of nanotechnology and advanced materials (in cooperation with the Austrian Social Insurance for Occupational Risks, AUVA), on the other.

Another important part of the *NanoTrust-Beyond* team's work is organizing and conducting conferences and workshops. Special attention will be given to the 16th *NanoTrust Conference on the Safe and Sustainable by Design (SSbD)* framework in the context of nanomaterials and advanced materials, scheduled for mid-October 2025, and is expected to serve as a key platform for interdisciplinary exchange on this emerging topic.

### 1.1.2 Nano Information Commission (NIK)

The Austrian Nano Information Commission (NIK) of the Austrian Federal Ministry of Social Affairs, Health, Care and Consumer Protection will begin its third function period (until 2028). The new NIK has been formed in 2024 for its constitutive meeting in the presence of the minister in charge, Dr. Johannes Rauch. Dr. André Gzásó, Institute of Technology Assessment, has been designated as chairman. Deputy chairwoman will be Prof. Dr. Eva Kathrin Ehmoser (Institute of Synthetic Bioarchitectures, BOKU University of Vienna). The more than 30 members are coming from academia, regulatory authorities and non-governmental organisations. The NIK convenes two to three times a year having as main tasks i) to provide all members with information on the current research and developments in the field of nanotechnology safety, ii) to offer an opportunity to discuss and evaluate these findings and iii) to foster safety-relevant research concerning the use of nanomaterials in Austria. The NIK is concerned with the implementation of the Austrian Nano Action Plan and represents the diversity of opinions and the professionally sound state-of-knowledge of various scientific experts. Invited speaker presented their actual scientific project, related to methodological developments and future perspectives.

The inaugural meeting of the Austrian Nano Information Commission (NIK) took place on June 24, 2024, at the Alfred-Dallinger Hall in Vienna with the chairperson, MMag. Dr. Gzásó, and the deputy chairperson, Univ.-Prof. Dr. Ehmoser.

Dr. Gzásó highlighted the origins of NIK and its role as an "honest broker" providing scientifically grounded recommendations for risk management. He expressed a desire for increased collaboration with international bodies and organizations, such as the OECD and German federal authorities. The deputy chairperson stressed the diverse perspectives brought by the members and encouraged active participation in discussions.

Reports were presented on various projects, including NanoTrust and CERANANO, which focus on the assessment of health and environmental risks associated with nanomaterials. The meeting concluded with a discussion on the patentability of nanoscale innovations.

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<sup>3</sup> Olscher, C., Gressler, S., Prenner, S., Jung-Waclik, S., Pavlicek, A., Resch, S., Falk, A., Gzásó, A., & Part, F. (2024). *Safe and Sustainable by Design (NanoTrust-Dossier Nr. 067 – Oktober 2024)* (p. 5). Wien. doi:/10.1553/ita-nt-067

<sup>4</sup> Prähauser, L., Wiessner, K., Gepp, B., Pavlicek, A., & Simböck, E. (2024). *Ökotoxikologische Risikobewertung von Nano- und Mikroplastik (NanoTrust-Dossier Nr. 066 – Dezember 2024)* (p. 7). Wien. doi:/10.1553/ita-nt-066

The second meeting of the Austrian Nanoinformation Commission was held on November 13, 2024, in Vienna. During the event, a presentation on advanced techniques for the analysis of individual particles in environmental systems was delivered by Prof. Dr. David Clases (Institute of Chemistry, University of Graz) and Ing. Dr. Christian Hill (Department of Medical Physics and Biophysics, Medical University of Graz). The presentation covered non-target screening methods, novel data processing platforms, and complementary single-particle analysis techniques

### **1.1.3 Updates from the Austrian Nanoinformation Commission Meeting:**

A research project commissioned by a Luxembourg-based manufacturer of single-wall carbon nanotubes (SWCNTs) for lithium-ion batteries was briefly presented by Florian Part (BOKU University). The aim was to determine whether carbon nanotubes (CNTs) are released during battery recycling. BOKU and AUVA jointly carried out aerosol measurements on behalf of the single-wall CNTs (SWCNTs) producer OSCiAl (Luxembourg). The laboratory scale measurements revealed that both fine and ultrafine particles and nanofibers are released through mechanical shredding processes. Using the patented sampling method, which is called 'identifier C2' from STAT PEEL and includes Raman spectroscopy and electron microscopy for fiber analysis, it was possible to quantify SWCNTs and differentiate them from multi-wall CNTs (MWCNTs) and further released cathode and anodes materials. Encouragingly, workplace concentrations were found to be below the recommended exposure limit of  $1 \mu\text{g}/\text{m}^3$  (8-hour average) set by the U.S. National Institute for Occupational Safety and Health (NIOSH). However, aerosol measurements and workplace evaluations on an industrial scale and in real battery recycling plants are needed to draw general conclusions on the dust loads.

### **1.1.4 Regulatory and Strategic Updates**

In a short presentation, Frau Mag. Simone Mühlegger reported on a German-Dutch initiative to establish a CARACAL subgroup for the development of EU-wide testing and validation strategies—also relevant for nanomaterials. CARACAL is an advisory body for the implementation of REACH and CLP regulations.

Dr. André Gzásó announced his retirement from ITA at the end of 2024. he has been handing over his responsibilities for the NanoTrust project to his successors, Dr. Mag. Gudrun Lettner and Ing. Jean Schmitt. Notably, the NanoTrust project, originally launched in 2007, has been extended under Dr. Gzásó's initiative as "NanoTrust Beyond" and will continue until 2027.

### **1.1.5 Report from the Working Group on Standardization**

Dr. André Gzásó, nearing retirement, handed over the chairmanship of Austrian Standards AG 052.73 "Nanotechnologies and Nanomaterials" to his deputy, Mag. Thomas Falta. Anna Pavlicek MSc. MSc. will now serve as deputy chair.

The reevaluation of the SSbD concept for nanomaterials and nanomaterial-containing products has been agreed to comprise a central aspect in nanotechnological research and development in Austria and aligns with the upcoming European Commission SSbD framework.

## **1.2 BIAC**

**BIAC** through the **NIA** contributed to the compilation of the document entitled "*Tools, integrative systems and platforms for nanomaterials and nano-enabled products*" produced under the OECD SSIA SG to support industrial implementation of Safe and Sustainable by Design. The NIA routinely participates in the OECD SG SSIA and AdMa, in particular in the case study of Graphene, where the NIA help organise and contributed to the OECD WPMN Expert Workshop on Graphene (Family Materials) held as a face-to-face

workshop in Paris in November 2024. The **NIA** took an active role in the implementation of the Malta Priority List regarding prioritisation of testing approaches for nanomaterials and has encouraged the development and adaptations of testing guidelines through different channels (e.g. ECHA, EFSA, recommendations made to the EU's Technology Council for Advanced Materials).

## 1.3 Canada

### 1.3.1 Risk assessment decisions, including the type of: (a) nanomaterials assessed; (b) testing recommended; and (c) outcomes of the assessment

The Government of Canada's New Substances program, jointly administered by Environment and Climate Change Canada and Health Canada, is responsible for assessing new substances under the purview of the *New Substances Notification Regulations (Chemicals and Polymers)* [NSNR(C&P)] of the *Canadian Environmental Protection Act, 1999* (CEPA). These regulations ensure that no new substances (chemicals or polymers) are introduced into the Canadian marketplace before undergoing ecological and human health assessments, and that any appropriate or required control measures have been taken. In total, under the NSNR (C&P) Canada has assessed **twelve** nanomaterials and substances with the potential to be produced at the nanoscale since WPMN24. In addition, two pre-notification consultations were completed. Pre-notification consultations provide clarity to the regulated parties, upon request, on regulatory requirements prior to submission of a new substance notification under the NSNR(C&P).

In addition, Canada continues the risk assessment of zinc oxide (ZnO) and titanium dioxide (TiO<sub>2</sub>) at the nanoscale that are in commerce in Canada, to evaluate their potential for environmental and human health risks under CEPA.

### 1.3.2 Risk management approaches

The New Substances program of Environment and Climate Change Canada and Health Canada published a Significant New Activity notice (SNAc) requiring anyone importing or manufacturing the substance iron potassium oxide as a nanomaterial, to provide updated study data on the nanoform in order to adequately assess the risk to human health and the environment <https://gazette.gc.ca/rp-pr/p1/2024/2024-11-09/html/notice-avis-eng.html#ns3>.

The New Substances program of Environment and Climate Change Canada and Health Canada published a Ministerial Condition on a multi-walled carbon nanotube substance to mitigate potential inhalation risk to human health. The decision is published here: Canada Gazette, Part 1, Volume 159, Number 10: GOVERNMENT NOTICES DEPARTMENT OF THE ENVIRONMENT (<https://gazette.gc.ca/rp-pr/p1/2025/2025-03-08/html/notice-avis-eng.html>)

## 1.4 Croatia

### 1.4.1 Risk assessment decisions, including the type of: (a) nanomaterials assessed; (b) testing recommended; and (c) outcomes of the assessment

Institute for Medical Research and Occupational Health (IMROH) in Zagreb (Prof. Ivana Vinković Vrček) is involved in the project ECHA/2022/502.Lot 2 "Methodological developments and data generation for the assessment and building of sets of nanoforms" (led by QSARLab Ltd, Gdansk, Poland) to provide services related to methodological developments and data generation for the assessment and building of sets of nanoforms and to support ECHA in its tasks. IMROH is also working on the development and implementation of novel advanced methodologies (NAMs) for efficacy and safety assessment of

nanomaterials and advanced materials to support Integrated Approaches to Testing and Assessment (IATA) to cover nano-specific considerations.

#### **1.4.2 Risk management approaches**

Regarding the development/optimization of experimental approaches for safety and risk assessment of nanomaterials and advanced materials, IMROH is performing activities on (i) optimization of dispersion protocols for iron oxide nanomaterials, (ii) stability evaluation (iii) assessment of particle uptake and crossing biological barriers using advanced models for intestinal, blood-brain and placental barrier, and (iv) in vitro assessment of developmental toxicity of meeting the definition of Article 3(27) REACH (Regulation 1907/2006) on the *in vitro* screening studies for the identification of different iron oxides forms (FeOx) with the highest biological activity in compliance with the Three R's (3R's - Replacement, Reduction and Refinement of animal testing) principles.

#### **1.4.3 New regulatory challenge(s) with respect to any action for nanomaterials and or advanced materials**

IMROH is also involved in development of analytical strategies for (i) assessing compliance with the ban of titanium dioxide (E 171) as a food additive on the EU market (Regulation (EU) 2022/63) considered by the recent EFSA risk assessments pertaining the use of nanomaterials in food and the subsequent regulatory decisions of the European Commission (EC).

### **1.5 European Union**

As also for historical reasons EU regulations in different sectors that include specific provisions on nanomaterials do not all use same definition of nanomaterial that triggers them, Commission issued a Recommendation on the definition of nanomaterial to be used for regulatory purposes, first in 2011 and revised in 2022<sup>5</sup>, to support harmonisation as regulations are reviewed. An alignment during revision of the 'engineered nanomaterial definition' of Regulation EU 2015/2283 in the food sector was however not approved by the European Parliament and the definition thus remains unchanged. Alignment is considered in the ongoing recast of the Regulation (EC) No 1223/2009 on cosmetics products, and in the revision of Regulation (EC) 1907/2006 (REACH) for which the adoption of Commission proposal is planned in December 2025.

In the REACH revision, update of the definition of nanoform is complemented by consideration of other changes to address implementation challenges on nanomaterials, notably with regard to the application of concept of set of similar nanoforms and implementation by downstream users.

European Chemicals Agency (ECHA) is as part of REACH implementation presently performing compliance checks of registrations covering nanoforms of TiO<sub>2</sub>, while substance evaluation of ZnO in nanoform is also ongoing.

ECHA is also currently working on the "Sameness Project on Nanomaterials", a two-year initiative aimed at developing enforceable criteria for determining the sameness and grouping of nanomaterials under REACH Annex VI:

- *Phase 1* of the project, which ran from August 2023 to August 2024, is now complete. It focused on conducting a comprehensive literature review (over 1000 papers) to identify existing frameworks and develop a draft decision-tree-based framework for assessing

<sup>5</sup> COMMISSION RECOMMENDATION of 10 June 2022 on the definition of nanomaterial, OJ C 229/1, 14.6.2022

sets of nanoforms based on key characteristics such as composition, size distribution, surface functionalisation, shape, and crystallinity.

- *Phase 2*, which began in September 2024 and will conclude in October 2025, is currently ongoing. This phase focuses on validating the draft framework through various case studies to test its robustness and identify areas for refinement.

European Observatory for Nanomaterials (EUON), coordinated by the ECHA and funded by the European Commission, continues to address knowledge gaps in nanomaterials through two annual review studies on emerging topics. In 2025, EUON has published the study “Survey on state of the art of carbon-based nanomaterial detection and quantification in environmental and biological matrices”, which evaluated methods for detection, characterisation, and quantification of carbon-based nanomaterials (CBNMs) in biological and environmental matrices, and provided recommendations and a roadmap to address gaps in research and regulatory science. A second study focusing on information on nano-enabled textiles is expected to be published by the end of the year. In addition, two new studies (to be published in 2026) have recently been commissioned: “Assessment of health and environmental hazards and risks of surface treated nanomaterials” and “Nanomaterials used as or integrated into flame retardants”.

European Food Safety Authority (EFSA) is continuing to work on the implementation of its 2021 Nano Guidance documents (i.e. ‘Guidance on risk assessment of nanomaterials to be applied in the food and feed chain: human and animal health’ (referred to as Guidance on Nano-Risk Assessment) and ‘Guidance on technical requirements for regulated food and feed product applications to establish the presence of small particles including nanoparticles’ (referred to as the Guidance on Particle-Technical Requirements)) for the assessment of regulated products.

Different routes of appraisal, as outlined in EFSA’s Guidance on Particle-Technical Requirements, have been applied in the assessment of regulated products across various EFSA domains to determine whether conventional risk assessment, conducted in accordance with the relevant sectoral guidance, was sufficient.

A full integration of nano risk characterisation was implemented in the context of the Re-evaluation of silicon dioxide (E 551) as a food additive in foods for infants below 16 weeks of age, as well as in the follow-up assessment of its use as a food additive for the general population. Given that synthetic amorphous silica (SAS), used as E 551, is insoluble or very slightly soluble in water, its assessment followed the EFSA Guidance on Nano-Risk Assessment in addition to conventional risk assessment approaches, as described in the sector-specific Guidance for the submission of Food Additives. This marked the first instance in which the principles of the 2021 Guidance on Nano-Risk Assessment were fully integrated into a weight of evidence (WoE) analysis in the context of food additives safety assessment.

Notable regulatory development includes imminent adoption<sup>6</sup> of regulation on the establishment of the common data platform on chemicals. Operational by 2028, the platform will integrate datasets of chemicals data (including nanomaterials) from different sectors, compiled and prepared by the European chemicals Agency in coordination with other EU Agencies. The provisions include work streams to help integrate datasets (substance identity, formats, identification of further relevant datasets to be incorporated), set consistent regime for reuse and several dedicated services from information on regulatory process across sectors, database of reference values, early warning and action system, data generation mechanism as well as the observatory on selected chemicals, embedding EUON (see above) but also enabling its expansion in particular towards advanced materials.

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<sup>6</sup> Council and the European Parliament reached a political agreement in June 2025 on the regulatory package proposed by the European Commission in 2023. The 2023 Commission proposal is available at the EUR-Lex website (<https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023PC0779>).

## 1.6 Germany

### 1.6.1 Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)

Five years after the nano-specific information requirements of the European Chemicals Regulation (REACH) came into force, the German Competent Authorities have assessed how these regulations are proving themselves in practice. In the report “Assessment of the enforceability of the rules for nanomaterials in REACH - review five years after entry into force”, they have identified hurdles and weaknesses within the current regulation that lead to insufficient data on the forms and applications of nanomaterials on the European market.

With regard to the upcoming revision of the European Chemicals Regulation, the CA report sees a clear need for adaptation and improvement in the following cases in particular:

- Necessary test methods are missing or not yet adapted to nanoforms.
- Due to the lack of an obligation to update registration dossiers, these are often not revised.
- Only a few registration dossiers of substances in nanoform have been reviewed by the European Chemicals Agency (ECHA) as part of the dossier evaluation.
- A lack of data continues to hamper the evaluation of substances.
- The concept of groups of similar nanoforms has proven to be too complex for registrants to apply with certainty. In addition, there are a number of ambiguities that are not easily resolved.
- If a downstream user manufactures a nanoform from a non-nanoform, this nanoform does not have to be registered. The relevant information is therefore not available to the regulatory authorities.

Based on their experience, the competent authorities have made some important proposals to amend the Chemicals Regulation. Germany has submitted them together with the report to the EU Commission for consideration in the REACH revision.

The revision process has already begun within the EU Commission, which has announced that it will present a first draft in Q4 2025.

### 1.6.2 Federal Institute for Risk Assessment (BfR)

The BfR (German Federal Institute for Risk Assessment) has been continuing the following risk assessment activities:

A second draft decision on the substance evaluation (SEv) of nano ZnO under the EU REACH regulation has been prepared and was submitted to ECHA (European Chemical Agency) for accordance check. Final discussion and adoption of the decision is scheduled for the 92<sup>nd</sup> Meeting of the Member State Committee (MSC-92) in December 2025.

The German higher federal authorities, BAuA (Federal Institute for Occupational Safety and Health) and the BfR are evaluating the possibilities for preparing a dossier to initiate a restriction procedure under the EU REACH regulation for substances in critical fibre form (length > 5 µm, width < 3 µm, aspect ratio > 3 : 1, and bio-persistent) with carcinogenic effects.

### 1.6.3 Federal Institute for Occupational Safety and Health (BAuA)

Based on a proposal by Germany the EU published a new harmonised classification of multi-walled carbon tubes (synthetic graphite in tubular shape) with a geometric tube diameter range  $\geq 30$  nm to < 3 µm and a length  $\geq 5$  µm and aspect ratio > 3:1, including multi-walled carbon nanotubes, MWC(N)T as Carc. 1B and STOT RE 1 in October 2024.

## 1.7 Italy

### 1.7.1 New regulatory challenges

The National Institute of Health (ISS) largely focused the activities in the area of regulatory risk assessment on the development of NAM-based approaches tailored to nano-specific safety assessment. This mainly occurred under the umbrella of the NAMs4NANO action (see Research programmes) dealing with nanomaterials in applications related to food and feed. In particular, as regards development/optimization of experimental methods, ISS continued ongoing activities on (i) in chemico methods for testing nanomaterial degradation/dissolution (ii) optimization of material-specific dispersion protocols (iii) assessment of intestinal particle uptake and crossing using advanced small intestine model (e.g. co-cultures of Caco-2 cells, HT29-MTX cells, and Raji B lymphocytes in both static and fluidic systems and intestinal reconstructed tissues).

Furthermore, ISS contributed to a RIVM-led experimental study on the effect of agglomeration and matrix of administration on the oral absorption of nanoparticles in vivo (2024-2026). The study aims at comparing (i) the effect of dispersion vs. absence of dispersion and (ii) the administration mode (gavage vs. via feed) on intestinal uptake and tissue accumulation of food-grade titanium dioxide. ISS co-designed the 90-day oral study on rats, developed the dispersion protocol, and checked the quality and stability of dispersion at different concentrations (corresponding to the different dose levels).

ISS also addressed challenges associated to recent EFSA risk assessments pertaining the use of nanomaterials in food and the subsequent regulatory decisions of the European Commission (EC). Such challenges included the development of analytical strategies for (i) assessing compliance with the ban of titanium dioxide (E 171) as a food additive on the EU market (Regulation (EU) 2022/63) (Bianchi et al., 2025) or (ii) checking the size specifications of iron hydroxide adipate tartrate (IHAT), the first nanomaterial authorised to be placed on the EU market under the Novel Food Regulation as an iron source in food supplements (Regulation (EU) 2022/1373) (Geiss et al., 2025) (see 'Developments related to good practice documents' for related publications). In this context, the National Reference Laboratory (NRL) for nanomaterials in food at ISS (<https://www.iss.it/en/Inr-nanoali>) continued to collaborate – as one of the six European expert laboratories in this field – with the EC Joint Research Centre in the area of regulatory analytical method development and harmonisation via the Nanomaterials in Food Laboratory Group (NIF-LAG).

The Italian Ministry of Health, as Competent Authority (CA) for Regulation (EC) 1907/2006 (REACH) and Regulation (EC) 1272/2008 (CLP), is part of the Partner Expert Group (PEG), coordinated by the European Chemicals Agency (ECHA), dealing with the update of the Guidance on the application of the CLP criteria Part 1 General principles for classification and labelling and Part 3 Health hazards, including inhalation toxicity of nanomaterials. The PEG written consultation on the proposed updates to the CLP Guidance is expected to take place in June-July 2025.

## 1.8 Portugal

In Portugal, the **National Institute of Health (INSA, Lisbon, Portugal)** develops investigation in the safety assessment of nanomaterials (hazard assessment). A contribution to genotoxicity assessment of cellulose nanomaterials, in compliance to OECD testing guidelines, has been recently published as an outcome of a PhD project:

- Vital N, Cardoso M, Kranendonk M, Silva MJ, Louro H. Evaluation of the cyto- and genotoxicity of two types of cellulose nanomaterials using human intestinal cells and in vitro digestion simulation. Arch Toxicol. 2025 Feb;99(2):575-596. doi: 10.1007/s00204-024-03911-2).

Previous contributions from INSA were related to the investigation of the toxicity and associated mechanisms of titanium dioxide nanomaterials, concerning the oral route of exposure and of nanofibers, e.g., carbon nanotubes and nanocelluloses, concerning inhalation. Some publications from those projects are as follows:

- Rolo D, Pereira JFS, Gonçalves L, Bettencourt A, Jordan P, Silva MJ, Matos P, Louro H. Assessing the impact of TiO<sub>2</sub> nanomaterials on intestinal cells: New evidence for epithelial translocation and potential pro-inflammatory effects. *Toxicology*. 2025 Feb; 511:154066. doi: 10.1016/j.tox.2025.154066.
- Vital N, Gramacho AC, Silva M, Cardoso M, Alvito P, Kranendonk M, Silva MJ, Louro H. Challenges of the Application of In Vitro Digestion for Nanomaterials Safety Assessment. *Foods*. 2024 May 28;13(11):1690. doi: 10.3390/foods13111690
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In addition, experts from **INSA** contribute to the elaboration of scientific opinions on nanomaterials in the context of food applications, through the participation in European Food Safety Authority (EFSA) or in the context of cosmetics, through the participation in the Scientific Committee on Consumer Safety (SCCS, European Commission).

The **University of Aveiro** (Aveiro, Portugal), through the Applied Ecology and Ecotoxicology Laboratory of the Department of Biology and through the Centre for Environmental and Marine Studies (CESAM) is enrolled in (eco)toxicological testing of nanomaterials, including the following recent papers: doi: 10.1016/j.impact.2024.100506; doi: 10.3390/toxics11060474; doi: 10.3390/toxics11020154.

The **University of Porto**, through the Research Unit on Applied Molecular Biosciences (UCIBIO), the Centre of Biotechnology and Fine Chemistry (CBQF) of the Universidade Católica Portuguesa (ESB/UCP) and the Associated Laboratory for Green Chemistry of the Network of Chemistry and Technology (LAQV-REQUIMTE), is developing a research project for improving the safety of fresh perishable food products with a sustainable bio-based cellulose packaging system incorporating a nanocomposite.

## 1.9 Sweden

### 1.9.1 Network for national government agencies

Building on the successful activities of the SweNanoSafe platform, which was decommissioned in December 2023, the [Swedish Chemicals Agency](#) (KEMI) launched a [network for national government agencies to address the safe handling of nanomaterials](#) in 2024. The network meets twice a year.

### 1.9.2 3D printers

Together with the Swedish Work Environment Authority, KEMI has published information and a set of safety recommendations to consumers using 3D printers.

### 1.9.3 SIO Grafen

[SIO Grafen is a national strategic innovation program](#) designed to support industrial development of graphene and other 2D materials in Sweden. SIO Grafen is funded by Sweden's innovation agency VINNOVA, the Swedish Energy Agency, and the Swedish research council for sustainable development FORMAS. The program is hosted by Chalmers Industriteknik. The goal is making 2D materials useful for society by making Sweden one of the leading countries in 2D materials. The programme has supported 220 projects, and 250 organisations have been involved over the last 11 years. During the last decade, Sweden has seen many startups initiating work in 2D materials and collaborating with large companies within a growing eco-system.

Some of these projects have focused on health aspects related to 2D materials. This work is led by occupational hygienists at Sahlgrenska University Hospital and has been focused on the work environment in laboratories and factories working with 2D materials. A quantitative exposure measure for graphene-related 2D materials has been developed and multiple measurement tools are evaluated and recommended for evaluation of occupational exposure to graphene-related 2D materials. Further methods are developed for more accurate toxicological testing of materials used in the actual work environment and not only for laboratory generated materials. This work is performed together with Karolinska Institutet.

### 1.9.4 Policy platform for advanced materials

Sweden's innovation agency [VINNOVA](#) has also supported a [project to develop a national policy platform for safe and sustainable advanced materials](#) (2023-2025, see further information [here](#)). Fifteen organisations were involved from the start and more have joined since then. These organisations range from small startups to large multinational corporations. The platform, coordinated by Chalmers Industriteknik, promotes innovation, conveys information, and promotes the responsible development of advanced materials. The platform also contributes to the development and implementation of policies, e.g., standards and regulations, which will support the uptake of advanced materials.

## 1.10 Thailand

The National Nanotechnology Center of Thailand (NANOTEC) promotes nanosafety through a range of initiatives. The Nano Safety and Bioactivity Research Team conducts safety testing on nanomaterials and is preparing its zebrafish testing model for OECD GLP certification. Kronolife, a deep-tech startup specializing in anti-aging solutions, provides R&D, testing services, and safety/efficacy evaluation for innovative nano-enabled products.

## 1.11 United States

Between June 2024 and May 2025, EPA received notification of one nanoscale substances based for a multiwalled carbon nanotube pursuant to its authority under the U.S. Toxic Substances Control Act (TSCA) section 8(a), bringing the total number of notifications to 90. Reporting criteria exempt nanoscale chemical substances already reported as new chemicals under TSCA and those nanoscale chemical substances that did not have unique or novel properties. Most reporting has been for metals or metal oxides.

Additionally, the EPA has under review 6 premanufacture notices, 4 of which are for multi-walled carbon nanotube chemical substances and two of which are for graphene materials. These 6 chemical substances are still being reviewed for potential risks to human health and the environment. One significant new use notice for a single-walled carbon nanotube is also under review for potential risks to human health and the environment.

Since January 2005, EPA has received and reviewed almost 300 new chemical notices for nanoscale materials under TSCA, including fullerenes and carbon nano-onions, quantum dots, semiconducting nanoparticles, and carbon nanotubes. EPA has issued consent orders and Significant New Use Rules (SNURs) regulating new chemical submissions of these nanoscale materials permitting manufacture under limited conditions. A manufacturer or processor wishing to engage in a designated significant new use identified in a SNUR must submit a Significant New Use Notice (SNUN) to EPA at least 90 days before engaging in the new use. A sanitized version (i.e., without confidential business information) of such a consent order is available. Because of confidential business information claims by submitters, EPA may not be allowed to reveal to the public the chemical substance as a nanoscale material in every new chemical SNUR it issues for nanoscale materials. EPA will continue to issue SNURs and consent orders for new chemical nanoscale materials in the coming year.

Because of limited data to assess nanomaterials, the consent orders and SNURS contain requirements to limit exposure to workers through the use of personal protective equipment, limit environmental exposure by not allowing releases to surface waters or direct releases to air and limit the specific applications/uses to those described in the new chemical notification.

## 1.12 ICAPO

Under the INSPIRE (IN vitro Systems to Predict REspiratory toxicity) Initiative, PETA Science Consortium International e.V. is using reconstructed human respiratory epithelium (RHRE; MucilAir, Epithelix) and a cell line (BEAS-2B) cultured at the air-liquid interface to assess two chemical classes (silanes published in [Sharma et al., 2023](#), and surfactants (*in preparation*)). While silanes were delivered to the cell systems as vapours (using a VITROCELL 6/4 exposure system), surfactants were administered as liquid (via pipetting) and as aerosols (VITROCELL® 6/4 system). Additionally, the MucilAir tissues were exposed to the two surfactants (Triton X-100 and oleoyl sarcosine) as both, a single (24 hours) or repeated exposure (4 hours/day for four consecutive days). Cellular effects assessed include cytotoxicity (lactate dehydrogenase release), cell viability (using resazurin-based PrestoBlue assay), secretion of interleukins-6 and 8 (CXCL-8; MSD V-Plex Assay), and additionally for MucilAir, transepithelial electrical resistance (TEER), cilia beat frequency (CBF), cilia average active area (AAA), and histology. The next steps include assessing these surfactants in an alveolar cell line and expanding the list of surfactants to test. The goal of this initiative is to help identify relevant cellular effects, generation and exposure methods, and model systems that may be most appropriate for use, depending on the purpose of testing. The results of this study will help increase scientific confidence in human cell-based methods to assess respiratory tissue irritation. The approaches used under this project are intended to be generally applicable and may be of relevance for the testing of nanomaterials as well.

PETA Science Consortium International e.V. is organizing a multi-laboratory study in which a RHRE (MucilAir, Epithelix) will be used to assess the potential of ~20 chemicals to cause respiratory tissue irritation. The study was carefully designed based on our learnings from the INSPIRE initiative (see above) as well as a thorough literature review on *in vitro* inhalation toxicity testing publications. The tissues are exposed to five concentrations of 30  $\mu\text{L}$  (~100  $\mu\text{L}/\text{cm}^2$ ) test substance and 24 hours after exposure, cellular effects are evaluated, including cytotoxicity (lactate dehydrogenase (LDH) release), cell viability (using the resazurin-based PrestoBlue™ assay), transepithelial electrical resistance (TEER), and histology. The data will be used to derive a point of departure for use in risk assessment. Should the data be convincing, the plan is to submit a Standard Project Submission Form (SPSF) to the OECD for inclusion in the WNT work plan. While this one method will not address the entire space of inhalation toxicity, it addresses a regulatory need and can subsequently be expanded or used in combination with other tools to address a broader range of needs.

To better understand the local metabolism of RHRE, RNA sequencing (RNAseq) was performed on MucilAir tissues (Epithelix) from four different regions (nasal, bronchial, small airways, and alveolar) and up to five donors per region. The data from the RNAseq was then compared to the human lung cell atlas. Preliminary data analysis indicates that, as expected, nasal and bronchial tissues tend to align more than with the more distal regions. This work was performed in collaboration with BASF and Helmholtz Munich.

# **2** Activities have been initiated to implement the OECD Recommendation of the Council on the Safety Testing and Assessment of Manufactured Nanomaterials

## **2.1 Austria**

Austria works on Guidance development regarding Environmental abiotic transformation of nanomaterials - a proposal for this project has been sent to WNT. The work is under the auspices of the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology ([www.bmk.gv.at](http://www.bmk.gv.at)); the administrative lead will be made by Environment Agency Austria with the scientific input of the University of Vienna (Frank von der Kammer). The scientific work was co-funded by the EU Horizon 2020 Project Gov4Nano.

Since 2022 a follow-up project funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) aims to develop a test guideline for the abiotic environmental transformation of nanomaterials. This project is coordinated by the Environment Agency Austria and the German Environmental Agency,

The Department of Environmental Geosciences of the University of Vienna (Frank von der Kammer) is working on the development of an OECD Test Guideline for the Solubility and Dissolution Rate of Nanomaterials under Environmental Conditions. This project combines the existing OECD project 3.10 (former US/DK) with a new project that develops a dynamic testing methodology. Funding is provided by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and Umweltbundesamt.

In parallel the Department of Environmental Geosciences of the University of Vienna (Frank von der Kammer) works on the development of a test guideline (TG) for the environmental transformation of nanomaterials and hetero agglomeration of nanomaterials. The work on the transformation of NM extends and complements the existing activities in developing a guidance document. These two topics are funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Furthermore, the Department of Environmental Geosciences of the University of Vienna (Frank von der Kammer) supports the OECD activities in finalizing the guidance document on nanomaterial removal in wastewater treatment plants and the guidance document on sample preparation and dosimetry.

## 2.2 BIAC

**BIAC** through the **NIA** supports the implementation of Test Guidelines adapted to nanomaterials through its participation in EU-funded initiatives devoted to such activities. These are iCare, nanoPass, LEARN and Desiderata. Under the finished project NanoHarmony, the NIA has co-authored a publication describing the Process Mentor, which represents an advice tool to help developers and users of TGs move smoothly through the TG development (<https://testguideline-development.org/>). The NIA also supports the dissemination of relevant information by broadly advertising events, as well as through member-only events. As part of Desiderata, the NIA has developed a radar tool to provide support on relevant policies and guidelines for sectors relevant for nano and advanced materials.

In addition, the **NIA** actively participates and provides comments to Guidelines under development through its participation at the OECD SGTA group and has contributed to the OECD guidance on sample preparation and dosimetry.

## 2.3 Canada

In 2024, Canada published a draft [Proposed Plan of Priorities<sup>7</sup>](#): substances prioritized for assessment under CEPA. The proposed priorities include the ongoing assessments of in-commerce nanoscale zinc oxide (ZnO) and nanoscale forms of titanium dioxide (TiO<sub>2</sub>) as well as nanoscale silver.

## 2.4 Croatia

Croatian Head of Delegation (Prof. Ivana Vinković Vrček) participates in the OECD WPMN steering groups for Testing and Assessment (SG TA), Exposure Measurement and Mitigation (SG8 Exposure), Safe and Sustainable Innovation Approach (SG SSIA) and Advanced Materials (SG AdMa), respectively. The work has involved contributions to working descriptions on each of these subjects. Currently, the activities are focused on updating the Guidance on Sample Preparation and Dosimetry document by reviewing and leading the subsections. In addition, Croatia contributed with comments on several international reports and surveys, including from ECHA and the EFSA.

## 2.5 European Union

The EC (JRC) together with Luxembourg has been leading the drafting of the updated Guidance on Sample Preparation and Dosimetry for the Safety Testing of Manufactured Nanomaterials, receiving successful endorsement by the 25th WPMN.

While not an activity per se, the following article has recently been published that reflects on the implementation of nanomaterial regulatory governance across the regions and the role OECD WPMN played in its evolution: Rasmussen K, Sayre P, Kobe A, Gonzalez M and Rauscher H (2025) 25 years of research and regulation: Is nanotechnology safe to commercialize? *Front. Toxicol.* 7:1629813. doi: 10.3389/ftox.2025.1629813.

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<sup>7</sup> <https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/implementing-modernized-cepa/plan-of-priorities-landing-page/proposed-plan-of-priorities.html>

## 2.6 Germany

### 2.6.1 German Environment Agency (UBA)

Since 2020, Germany is leading OECD WNT project 3.10. “New TG on dissolution rate of nanomaterials in aquatic environment” for the investigation of solubility and dissolution rate under relevant environmental conditions.

To test reliability, repeatability and robustness of the test protocols developed for this anticipated TG, an ILC was conducted in spring/summer 2024. Methods and results of the ILC were discussed with the JEG on Environmental Fate and Toxicity of Nanomaterials in November 2024. In March 2025 the draft TG and draft ILC report was submitted to the JEG for a first commenting round. It is planned to submit the draft TG for WNT commenting rounds in autumn 2025 and strive for adoption at WNT 38 in 2026.

The associated research project launched by UBA in autumn 2019 was finalised in summer 2024. The final report entitled “Standardization of methods on the fate and behaviour of nanomaterials in environmental media – dissolution and dissolution rate” describes the scientific steps to develop the anticipated OECD TG. It summarises the relevant preliminary considerations and experimental work for the development of the methodological approach, the derivation of the various test approaches and the validation of these within the framework of an international ring test. The report is available at the website of UBA on nanomaterials: <https://www.umweltbundesamt.de/en/topics/chemicals/nanotechnology/research-development-projects-on-nanomaterials>

Since 2022, Austria and Germany are co-leading WNT project 3.16 “Guidance Document Environmental abiotic transformation of nanomaterials”. This project aims to provide science-based protocols to determine abiotic transformation of nanomaterials under environmental conditions. Since 2021, this WNT project is supported by a research project launched by UBA to provide the experimental and conceptual work to develop and validate as far as possible test procedures and conditions. The project named “OECD Test Guideline development for nanomaterials: transformation of nanomaterials under environmental conditions” can be found at the UBA website: <https://www.umweltbundesamt.de/en/topics/chemicals/nanotechnology/research-development-projects-on-nanomaterials>. As part of this project a comparison study was started in spring 2025. Based on the experiences gained, a draft GD will be drafted and shared with the JEG on Environmental Fate and Toxicity of Nanomaterials in autumn 2025. WNT commenting rounds are scheduled for 2026, adoption as OECD GD is planned for WNT 39 in 2027.

In the same research project, procedures and conditions for the testing hetero-agglomeration under environmental conditions are investigated and a SOP has been developed. As part of this project an ILC was started in spring 2025. The outcome of the project is considered for an update of OECD TG and GD 318.

### 2.6.2 Federal Institute for Occupational Safety and Health (BAuA)

BAuA is leading a work package in the EU-project MACRAMÉ on “Translation into Standards Policy-Information”. Within MACRAMÉ we continued the successful November workshops on TG development for nanomaterials. The [2nd Joint Workshop: Harmonisation & Standardisation of Test Methods for Nanomaterials and Advanced Materials](#) was held on 18. – 19. November 2024 in collaboration with the Malta Initiative and the EU-funded projects iCare, nanoPASS and ACCORDs. The two-day online workshop focused on next generation risk assessment, NAMs, computational methods, imaging and the assessment of complex samples along the life cycle. The next Harmonisation & Standardisation Workshop will take place in November 2025 (online). Information and registration will be shared on the [MACRAMÉ webpage](#).

Within MACRAMÉ BAuA organised a webinar on overcoming issues in regulatory testing of advanced materials. The webinar can be re-listened [here](#).

BAuA together with the project partners UBA, BfR (Germany), NRCWE (Denmark), LEITAT (Spain) and ECHA continued the work in the project for the development of an OECD Guidance on Release Test for Manufactured Nanomaterials. The draft guidance contains an overview of standardised and not yet standardised release tests as well as a decision framework on the choice of suitable release test methods and a link to possible applications of gained release test data for regulatory assessments. Exchange with the SG8 experts is envisioned for summer 2025.

## 2.7 Italy

The activities related to the drafting of the Guidance Document (GD) on an in vitro approach for the intestinal fate of ingested nanomaterials (OECD WNT Project 4.158) continued and were carried out within the framework of the Task Force set up by the Working Group on Nanomaterials, coordinated by the Italian Ministry of Health. After the first submission of the GD draft, the revised version, according to the comments received by the OECD International Expert Group (IEG), is under internal discussion involving all national experts and the national coordinator of the OECD WNT Test Guideline Project. The final submission of the project to the WNT is expected by Q1 2026.

## 2.8 Portugal

Further to the representation of Portugal in the OECD WPMN, with an expert from the **National Institute of Health (INSA, Lisbon)**, the experts from INSA are involved in activities in the European Food Safety Authority (EFSA), in the Cross-cutting Working Group on Nanotechnologies and at the Scientific Committee on Consumer Safety – Working Group on nano (SCCS), where the recommendation is taken on board for the risk assessment of food/feed or cosmetic ingredients containing nanomaterials, contributing to the elaboration of scientific opinions. Currently, an expert from **INSA** is contributing to the revision of EFSA guidance for the risk assessment of nanomaterials to be applied in food sector in Europe.

The **University of Aveiro** is also enrolled in OECD Test Guidelines for their Applicability to Manufactured Nanomaterials (environment); use non-standardized model organisms and endpoints in nanomaterial testing (environment); fate, ecotoxicity, bioaccumulation and toxicokinetics (environment) annex for the OECD GD 317, adaptations proposed to the OCED TG 202 (and also collaboration on the 201 and 203).

## 2.9 Switzerland

The Swiss Federal Agency has updated the InfoNano website. InfoNano is the Swiss federal government's central information hub for nanotechnology. It provides information on the opportunities and risks associated with nanomaterials, their applications, and the completed action plan for synthetic nanomaterials (2008–19). Key topics include guidelines on safe use, the promotion of public dialogue and key research, as well as regulatory updates on the risks and opportunities of nanomaterials.

The State Secretariat for Economic Affairs carried out a preliminary campaign to review the self-regulation of notified nanomaterials, based on the Swiss Chemical Ordinance, with a focus on worker protection and safety data sheets (SDS).

## 2.10 United Kingdom

### **2.10.1 OECD Project 4.174: Validating the In Vitro Micronucleus assay for Engineered Nanomaterials**

The “Study Report and Preliminary Guidance on the Adaptation of the In Vitro micronucleus assay (OECD TG 487) for Testing of Manufactured Nanomaterials” was published by the OECD in Sept 2022. This document provides an adapted protocol for the evaluation of nanomaterial genotoxicity using the in vitro micronucleus assay, addressing several key issues in the required experimental approach. However, some issues were not possible to address in the published GD. To address these limitations, OECD project 4.174 has been initiated being co-led by the UK and Germany, which involves an inter-laboratory trial utilising the Standard Operating Procedure (SOP) that has been previously defined. The aim of this project is to produce an adaptation of OECD TG487 to include the methodological requirements that ensure the approach taken is appropriate for nanomaterials.

### **2.10.2 OECD GD on Toxicokinetics for nanomaterials**

OECD Project on GD on Toxicokinetics for nanomaterials (Netherlands lead, UK co-lead). The expert group is convening in May and have produced an advanced draft and are on schedule to have a full version for comments in September.

# 3 Developments related to good practice documents

## 3.1 BIAC

**BIAC** through the **NIA** follows standardisation activities through ISO/TC 229 Nanotechnologies and CEN/TC 352 Nanotechnologies. Relevant updates from those activities are communicated to NIA members through the NIA newsletter and at relevant events organised by the NIA.

Through the EU iCare project, the NIA promotes the development of a Standard Operating Procedure (SOP) inventory focusing on neurotoxicity and alternatives, supporting the development and regulatory update of NAMs. The NIA has also been supporting standardisation activities of NAMs under the EU project nanoPASS supporting the development of new assays for 2 AOPs (reduced lung function - AOP302; cardiovascular disease - AOP237).

**BIAC** through **Solvay** participates in the Particles Platform, which is an alliance of 25 EU industry associations from the chemicals and metals sectors. Its purpose is to enhance scientific understanding, share information, and find practical solutions for regulations related to particle materials.

The Platform addresses the challenges associated with particles and their hazard assessment. More information can be found on their website: <https://www.particlesplatform.eu/>.

A scientific workshop will be held on October 2 in Brussels, where industry and authority stakeholders will discuss particle inhalation and hazard assessment. Remote participation is available.

## 3.2 Croatia

The experts from IMROH actively participated to the work on updating the Guidance on Sample Preparation and Dosimetry document by reviewing and leading the subsections. Furthermore, Croatia is involved in the Steering Group on Safety Testing on Nanoplastics and in the development of the Guidance document on toxicokinetics to accommodate testing of (nano)particles.

Furthermore, Croatian Head of Delegation is involved as expert in the EFSA Cross-cutting Working Group on Particle Risk Assessment establish to update guidance document for risk assessment of nanomaterials and materials containing nanoparticles in the food chain, as well in the EFSA Scientific Panel on Additives and Products or Substances Used in Animal Feed with the aim to build Guidance document on nanoparticles in feed additives.

## 3.3 European Union

JRC and DG SANTE (Directorate-General for Health and Food Safety) co-operate on Nanomaterials in Food and support EU member states in their enforcement duties of EU food law and associated legal

requirements. Thus, the JRC provides training to official control laboratories, develops analytical methods and strategies to facilitate the characterisation of nanoscale materials in food by, and contributes to ongoing standardisation efforts in the European Committee for Standardization (CEN), and has provided laboratory data and participates to the drafting of a CEN technical specification “Nanotechnologies - Guidelines for the characterization of nanoobjects-containing additives in food products”. JRC work has focused on gathering data on the content of TiO<sub>2</sub> in food products and developing a screening Raman spectroscopic method for assessing compliance with the EU ban of titanium dioxide as food additive (Regulation (EU) 2022/63). The outcomes of this work are shared in two papers: (1) G. Bucher, H. El Hadri, O. Asensio, F. Auger, J. Barrero, J.-P. Rosec. Large-scale screening of E171 food additive (TiO<sub>2</sub>) on the French market from 2018 to 2022: Occurrence and particle size distribution in various food categories. *Food Control*, Vol. 155, January 2024, 110102 (<https://doi.org/10.1016/j.foodcont.2023.110102>), and (2) I. Bianchi, H. El Hadri, O. Geiss, K. Cheyns, J. Mast, F. Ferraris, F. Cubadda, K. El Hanafi, J.-P. Rosec, F. Auger, J. Barrero-Moreno. A screening method for detection of TiO<sub>2</sub> in food based on Raman spectroscopy and its applicability in a regulatory context. *Food Control*, Vol. 168, February 2025, 110868, <https://doi.org/10.1016/j.foodcont.2024.110868>

The JRC also coordinates the Nanomaterials in Food Laboratory Group (NIF-LAG), whose members are expert laboratories from Belgium, France, Denmark, Germany, Italy and the Netherlands. Some of these laboratories also act as national reference laboratories and official national control laboratories.

Nanocellulose has attracted significant attention in recent years due to its vast potential for application in various fields including the food sector. JRC is performing a research study using a range of analytical techniques, including batch mode dynamic light scattering (DLS), asymmetric flow field-flow fractionation (AF4) coupled to multi-angle light scattering (MALS) and DLS, and transmission electron microscopy (TEM), to characterize the size and shape of various nanocellulose types such as crystalline, fibrillated and bacterial nanocellulose.

The JRC, together with colleagues from Sciensano (Belgium), have published a scientific paper that offer an experimental approach for determining the minimum particle count to measure particle size and shape by electron microscopy. This is relevant for (EU) legislation that requires reliable nanomaterial characterisation data, for which regulatory guidance may recommend electron microscopy, as guidance, including OECD TG 125, lack requirements on how many particles to measure. Based on experimental data, the paper proposes a strategy to establish, for different particle size and shape measurands, mathematical relationships between particle count and precision, and subsequently to determine the minimum particle count. The results confirm that the minimum particle count generally depends on the width of the size and shape distributions and that the median of the distribution can be determined with the highest precision compared to other percentiles. Upon combining the precision uncertainty related to particle number with uncertainties from other sources (e.g. sample preparation, calibration and trueness), an optimal particle count is reached above which additional particle measurements only yield negligible improvements to the combined measurement uncertainty. The findings offer an experimental approach for determining the minimum particle count to measure particle size and shape by electron microscopy. It enables efficient analyses and facilitates compliance with legislation addressing nanomaterials across various application domains. The paper is: C. Wouters, E. Verleysen, J. Mast, V. Kestens. Assessing particle count in electron microscopy measurements of nanomaterials to support regulatory guidance. *Sci Rep* 15, 11803 (2025). <https://doi.org/10.1038/s41598-025-92266-4>

EFSA: Based on experience gained in the application of the 2021 EFSA Nano Guidance documents (i.e. ‘Guidance on risk assessment of nanomaterials to be applied in the food and feed chain: human and animal health’ and ‘Guidance on technical requirements for regulated food and feed product applications to establish the presence of small particles including nanoparticles’) to practical cases and consultation with stakeholders, various elements for improvement were identified. This has led to publication of additional provisions and clarifications to supplement the existing guidance documents, and the following were published in 2024:

- [Clarification on the use of Dynamic Light Scattering \(DLS\) and other light scattering methods for characterisation of particle size distribution, 50th meeting of the Working Group on Nanotechnologies, Annex I](#)
- [Annex B: Clarification on the use of a Kow-based threshold for lipid-soluble \(lipophilic\) substances as a possible appraisal route.](#)
- [Annex C: Practical instructions for reporting the results of electron microscopy analysis of nanomaterials or materials possibly containing a fraction of small particles including nanoparticles.](#)
- [Annex D: Reporting template for an electron microscopy analysis and results.](#)

Addressing other identified issues and areas for potential improvement, however, needed further actions to enhance the guidance to support both the applicants and the risk assessors. This has resulted in a new EFSA self-task mandate to develop an updated guidance for the risk assessment of nanomaterials and materials containing small/nano particles in the food and feed chain (M-2024-00062). A series of engagement activities are being planned to increase international cooperation and facilitate stakeholder interaction. A stepwise approach is being implemented to ensure constructive dialogue and harmonisation of scientific requirements. This process began with an initial consultation held from 29 December 2024 to 14 February 2025 to gather input on the mandate objectives and Terms of Reference. This has fed the development of a scoping paper, which outlines the proposed strategy for the guidance update, including a draft structure for the new merged guidance and key content issues to be addressed in the revised document. The scoping paper was published for public consultation until 20 May 2025 and was open for discussion in a dedicated workshop, which was held on 11-12 June 2025 in Brussels. The aim of this event was to gather inputs on the proposed approach for guidance update and discuss with stakeholders and other regulatory agencies on fundamental scientific aspects. In addition, EFSA is actively collaborating with national and international regulatory entities through a dedicated Scientific Network for Risk Assessment of Nanotechnologies in Food and Feed, where the guidance update engagement plan has been shared (14th NanoNetwork, November 26-27th). In light of EFSA's commitment to co-creation, the Network will be requested to contribute to the development of an updated EFSA's nanomaterials and nanotechnology guidance.

In 2025, EFSA initiated a self-task mandate of the Panel on Additives and Products or Substances used in Animal Feed (FEEDAP) to develop a specific guidance document for the risk assessment of feed additives containing nanoparticles (M-2024-00163). The first phase addressing target animal safety and dissolution testing relevant for target animal species is expected to be finalised in 3 years.

## 3.4 Germany

### 3.4.1 Federal Institute for Risk Assessment (BfR)

Two OECD Guidance Documents (GD), initiated within the EU NanoHarmony project (ended 10/2023), are being developed under the co-leadership of the BfR:

- GD on “Determination of Solubility and the Dissolution rate of Nanomaterials in Water and Relevant Synthetic Biological Media” (WNT Project 1.5).
- GD on “Identification and Quantification of the Surface Chemistry and Coatings for Nano- and Microscale Materials” (WNT Project 1.6).

The latest draft of the GD on “Identification and Quantification of Surface Chemistry and Coatings on Nano- and Microscale Materials” is available for commenting in the Joint Expert Group and then WNT. The other GD will be finalised soon and will be shared with the Joint Expert Group and then the WNT for commenting.

The BfR contributes to the OECD WNT Project 4.174: “Validation of the In Vitro Micronucleus assay (OECD TG 487) for Engineered Nanomaterials” in two different functions:

- The BfR in its function as a member of the WNT for Germany (human health) coordinates the activities of project 4.174 as co-lead with UK, FR and NO.
- The BfR is contributing to the activities of the project 4.174 as a testing laboratory. A proficiency test is currently being carried out with all the participating test laboratories using the Standard Operating Procedures (SOPs) defined within the preliminary guidance (ENV/CBC/MONO(2022)15).

In addition, the BfR contributes to the OECD WNT Project 4.146 “Development of an OECD Guidance Document to accommodate the toxicokinetic assessment of nanomaterials”, lead jointly by RIVM (National Institute for Public Health and the Environment) of the Netherlands and UKHSA (The UK Health Security Agency). A literature overview on the toxicokinetic studies of CeO<sub>2</sub> nanoparticles has been provided by the BfR.

### 3.4.2 Federal Institute for Occupational Safety and Health (BAuA)

The use of nano-sized fibre materials, such as carbon nanotubes (CNTs) and inorganic nanofibres, is of increasing technological importance. To ensure the safety of employees who are exposed to critical fibre dusts from these materials in the workplace, an EU-wide standardised measurement method is required to reliably record the concentration of critical nanofibres in the breathing air. A new Technical Specification (TS) was developed for this purpose to which BAuA contributed with the identification of suitable air sampling systems and the development and validation of specific counting rules for electron microscopy. Workplace exposure - Detection and characterization of airborne NOAA using electron microscopy - Rules for sampling and analysis; CEN/TS 18117:2025

(<https://www.dinmedia.de/en/standard/pd-cen-ts-18117/390542449>).

## 3.5 Italy

### 3.5.1 Publications on SSbD approaches

- Karakoltzidis A., Battistelli C.L., Bossa C., Bouman E.A., Garmendia Aguirre I., Iavicoli I., Zare Jeddi M., Karakitsios S., Leso V., Løfstedt M., Magagna B., Sarigiannis D., Schultes E., Soeteman Hernandez L.G., Subramanian V., Nymark P. 2024. The FAIR principles as a key enabler to operationalize safe and sustainable by design approaches. *RSC Sustainability* 2, 3464. DOI: 10.1039/d4su00171k

### 3.5.2 Publications on NAMs in hazard assessment of nanomaterials

- Haase A., Barroso J., Bogni A., Bremer-Hoffmann S., Fessard V., Gutleb A.C., Mast J., McVey E., Mertens B., Oomen A.G., Ritz V., Serchi T., Siewert K., Stanco D., Usmani S.M., Verleysen E., Vincentini O., van der Zande M., Cubadda F. 2024. Proposal for a fit for purpose qualification system for New Approach Methodologies (NAMs) in the food and feed sector. EFSA supporting publications 21(9):EN-9008, 96 pp.
- Usmani S.M., Bremer-Hoffmann S., Cheyns K., Cubadda F., Dumit V.I., Escher S.E., Fessard V., Gutleb A.C., Léger T., Liu Y.-C., Mast J., McVey E., Mertens B., Montalvo D., Oomen A.G., Ritz V., Serchi T., Sieg H., Siewert K., Stanco D., Verleysen E., Vincentini O., Yeo C.W.S., Yu D., van der Zande M., Haase A. 2024. Review of New Approach Methodologies for Application in Risk

Assessment of Nanoparticles in the Food and Feed Sector: Status and Challenges. EFSA supporting publications 21(9):EN-8826, 178 pp.

### 3.5.3 Publications on development of analytical methods for nanomaterials in food

- Geiss O., Bianchi I., El Hadri H., Ponti J., Brassinne F., Wouters C., Mast J., Loeschner K., Givelet L., Cubadda F., Raggi A., Ferraris F., Gräf V., Devy Mantovan E., Zanella M., Benetti F., Barrero-Moreno J. Particle size analysis of iron hydroxide adipate tartrate (IHAT) in a food supplement: Interlaboratory testing of a dynamic light scattering method. *Journal of Food Composition and Analysis* **137**:106866.
- Bianchi I., El Hadri H., Geiss O., Cheyns K., Mast J., Ferraris F., Cubadda F., El Hanafi K., Rosec J.-P., Auger F., Barrero-Moreno J. 2025. A screening method for detection of TiO<sub>2</sub> in food based on Raman spectroscopy and its applicability in a regulatory context. *Food Control* **168**:110868.

### 3.5.4 Publications on occupational exposure and risk prevention

- Boccuni F, Tombolini F, Natale C, Bellagamba I, Sebastiani F, Ferrante R. 2024. Prevention-through-design approach to mitigate workers' exposure in the graphene production processes. *Journal of Physics: Conference Series* 2695:012003.
- Boccuni F, Tombolini F, Ferrante R. 2024. Risk prevention and training approaches for safety and health in graphene production processes. *Annals of Work Exposures and Health* 68 (1): i52.
- Natale C., Tombolini F., Ferrante R., Sebastiani F., Gordiani A., Manigrasso M., Del Rio Castillo A.E., Bonaccorso F., Sabella S., Boccuni F. 2025. Scaling up the graphene production from R&D to the pilot plant stage: Implications for workers' exposure to airborne nano-objects. *NanoImpact* 38, 100555.

## 3.6 Japan

The Japanese Industrial Standards Committee (JISC), which is the national member body participating as a P-member in ISO/TC229 (Nanotechnologies), nominated the Convenor and Secretary of TC229/JWG2 (Measurement and characterisation). In TC229/JWG2, JISC jointly (with ANSI, the American National Standards Institute) leads a project "Analysis of nano-objects using asymmetrical-flow and centrifugal field-flow fractionation" (IS 21362), and now this goes into the publication process. JISC leads "Positron annihilation lifetime measurement for nanopore evaluation in materials" (TS 23397), and now this has been published. In TC229/WG3 (Health, Safety and Environmental Aspects of Nanotechnologies), JISC leads "Characteristics of working suspensions of nano-objects for invitro assays to evaluate inherent nano-object toxicity" (IS 19337), and now this is published. JISC leads "Evaluation method for chronic inhalation toxicity based on lung burden of nanomaterials" (PWI 7666), and now this is under discussion. JISC leads "Method for the removal of carbon nanomaterials from wastewater using hypochlorite" (PWI21497), and this is under discussion. In TC229/WG4 (Material specification), JISC leads "Silica nanomaterials -Specifications of characteristics and measurement methods for nanostructured porous silica samples with ordered nanopore array" (TS 22298), now this has been published. JISC leads "Nanocomposite materials for insulating - Specification of characteristics and measurement methods" (PWI 12948), now this is under discussion. JISC leads "Specifications of characteristics and measurement methods of the zeolite membranes used for separation applications" (PWI 25400), now this is under discussion.

### 3.7 Korea

The nano safety metrology centre of Ministry of Science and ICT has published 1 standard and is developing 2 additional new items in ISO/TC 229 Nanotechnologies.

#### Published:

- ISO/IS 4962:2024 Nanotechnologies – In vitro acute nanoparticle phototoxicity assay

#### Under development:

- ISO/PWI Nanotechnologies – Intratracheal instillation procedure for the even distribution of nanomaterials in the rodent lung (WG3)
- ISO/PWI Nanotechnologies – Gold nanoparticle-a control for in vitro nanotoxicity assay (WG3)

### 3.8 Thailand

The Nanotechnology Society Awareness section collaborates with regulatory bodies, technical support organisations, and industry stakeholders to promote nanosafety and standards through seminars, conferences and workshops. The Nanotechnology Association of Thailand has expanded the NanoQ certification to four categories: Nanoproducts, Intermediate Nanoproducts, Nanoencapsulation and Raw Materials. Thailand has also initiated dialogue on mutual recognition of nanolabels (NanoQ and NanoVerify) with Malaysia's NanoVerify programme.

NANOTEC works with the Thai Industrial Standards Institute (TISI) to develop national nanotechnology standards. In 2024, two new standards were published:

- Indian Gooseberry Extract Nano-Encapsulated Particles (Standard No. 3748-2567)
- Pueraria Candollei Extract Nano-Encapsulated Particles (Standard No. 3749-2567)

### 3.9 The Netherlands

The Dutch Ministry of Infrastructure and Water Management organised a policy Conference '**European Test Method & Validation Strategy for Regulatory Chemical Risk Assessment** – Need for prioritisation, coordination & structural funding' on 22 & 23 January 2025 in Amsterdam, it addressed the slow progress in developing innovative test methods for hazard and risk assessment of chemicals and materials and the need for better test methods. The goal was to foster support and commitment for a European strategy that accelerates the availability of regulatory-accepted test methods. Seventy people from 15 European countries participated in the conference. These represented EU and national levels, public and private sectors, OECD, NGOs and other relevant organisations. The outcomes are presented in a [public chairmen's report](#). Outcomes include that shared responsibility among all key stakeholders is required for an effective governance of such a strategy. A collaborative approach is essential for efficient upfront prioritisation and coordination together with addition, structural funding. Current efforts are fragmented in silos, resulting in promising test methods failing to achieve regulatory acceptance. This strategy should extend beyond regulations such as REACH and CLP, engaging the whole chemical safety assessment community. Additionally, it is important to find connections and align with existing and upcoming EU initiatives, such as the [Chemical Industry Package](#) and the [Roadmap towards phasing out animal testing](#). The Ministry will initiate follow-up action in the course of 2025.

The Netherlands (RIVM) and UK (UKHSA) are leading the development of an OECD Guidance Document to accommodate the toxicokinetic assessment of nanomaterials (OECD TGP Project 4.146). Scientific input from the NanoHarmony project is used together with other (existing) information to come to guidance.

The Guidance Document will discuss the dosing regimen, duration of the post-exposure period, time points for determining organ/tissue burdens and key organs/tissues to be analysed. The dissolution rate in physiologically relevant media is considered to steer the study design. The Guidance document will also discuss analytical methods. Both the inhalation and the oral exposure routes will be covered in the new Guidance Document. A first draft has been shared with the Joint Expert Group and comments are discussed during a virtual meeting in May 2025. This included alignment with the update of the WPMN document Guidance on Sample Preparation and Dosimetry for the Safety Testing of Manufactured Nanomaterials with which there are multiple connections.

The Netherlands is involved in **CEN/TC 352/WG 3 “Health, safety and environmental aspects”** in developing two new standards. These consider Safe-by-Design concept dedicated for nanoscale materials (MNM) and products containing nanomaterials (prCEN/TS, PWI 00352047) and a Quick start guide for deploying a relevant nano health and safety risk management (prCEN/TS, PWI 00352040). Both are still under development.

Furthermore, The Netherlands is involved in **CEN/TC 137/WG 3 “Workplace exposure to Particulate matter”**. This WG 3 is revising several standards (EN 481 – Size Fraction Definitions for Airborne Particles, the EN 15051 documents – Measurement of the Dustiness of Bulk Materials, and EN 17199-5 – Measurement of Dustiness of Bulk materials that Contain or Release Respirable NOAAs – Vortex Shaker). In addition, two new standards have been published ([CEN/TS 18117:2025](#) “Workplace Exposure – Detection and Characterization of Airborne NOAA using Electron Microscopy – Rules for Sampling and Analysis” and [CEN/TS 18086:2024](#) “Workplace Exposure – Direct-Reading Low-Cost Particulate Matter Sensors for Measuring Airborne NOAA – Guidelines for application”).

### 3.10 Portugal

The **Portuguese ISO/CEN Technical Commission for Nanotechnologies (CT 194)**, that mirrors CEN/TC 352 and ISO/TC 229, develops activities in translation and development of standards, under the management of the **Portuguese Quality Institute (IPQ)** and the secretariat of **Interface and technology center (ISQ)**. Approximately 58 Portuguese institutions are involved, including the **National Institute of Health (INSA)**, **University of Aveiro**, **University of Coimbra**, **University of Porto**, **Faculty of Pharmacy of Lisbon University** and **CeNTI**, among others. In Sub-commission IV, issues related to Health, safety and environment are the main topics. Under this Technical Commission, a number of technical guidance and technical reports have been translated into Portuguese, and the development of new standards has been supported. A yearly national workshop under the title: “Nanotecnologies”, has been held in **Portuguese Engineers Association** (Ordem dos Engenheiros) and open to general public, to disseminate the preparation of standards related to nanosafety.

A recent work lead by Portugal, under the **European Partnership for the Assessment of Risks from Chemicals (PARC)** has reviewed the regulatory practices on the genotoxicity testing of nanomaterials and outlook for the future:

Andreoli C, Dusinska M, Bossa C, Battistelli CL, Silva MJ, Louro H. Regulatory practices on the genotoxicity testing of nanomaterials and outlook for the future. *Regul Toxicol Pharmacol*. 2025 Jun 6;162:105881. doi: 10.1016/j.yrtph.2025.105881

**INSA** has prepared standard operating procedures for *in vitro* genotoxicity testing of nanomaterials, applied either directly or after mimicking human digestion, and these procedures have been used in recent literature listed below. Recent notable publications by INSA scientists, in both popular and technical literature, include the following:

- Rolo D, Pereira JFS, Gonçalves L, Bettencourt A, Jordan P, Silva MJ, Matos P, Louro H. 2025. Assessing the impact of TiO<sub>2</sub> nanomaterials on intestinal cells: new evidence for epithelial

translocation and potential pro-inflammatory effects. *Toxicology*. Volume 511, February 2025, 154066. doi: 10.1016/j.tox.2025.154066. <https://doi.org/10.1016/j.tox.2025.154066>

- SCCS (Scientific Committee on Consumer Safety), U. Bernauer, L. Bodin, Q. Chaudhry, P.J. Coenraads, J. Ezendam, E. Gaffet, C. L. Galli, E. Panteri, V. Rogiers, Ch. Rousselle, M. Stepnik, T. Vanhaecke, S. Wijnhoven, E. Benfentati, N. Cabaton, E. Corsini, A. Koutsodimou, H. Louro, W. Uter, N. von Goetz. 2024. *Opinion on new coating for Titanium Dioxide (nano form)* - SCCS/1667/24. 25 October 2024, SCCS/1667/24. [https://health.ec.europa.eu/publications/sccs-opinion-new-coating-titanium-dioxide-nano-form\\_en](https://health.ec.europa.eu/publications/sccs-opinion-new-coating-titanium-dioxide-nano-form_en)
- Vital N, Cardoso M, Kranendonk M, Silva MJ, Louro H. Evaluation of the cyto- and genotoxicity of two types of cellulose nanomaterials using human intestinal cells and in vitro digestion simulation. *Arch Toxicol*. 2025 Feb;99(2):575-596. doi: 10.1007/s00204-024-03911-2.
- Vital N, Gramacho AC, Silva M, Cardoso M, Alvito P, Kranendonk M, Silva MJ, Louro H. *Challenges of the Application of In Vitro Digestion for Nanomaterials Safety Assessment*. *Foods*. 2024 May 28;13(11):1690. doi: 10.3390/foods13111690.
- SCCS (Scientific Committee on Consumer Safety), Bernauer L. Bodin Q. Chaudhry, P.J. Coenraads, M. Dusinska, J. Ezendam, E. Gaffet, C. L. Galli, E. Panteri, V. Rogiers, Ch. Rousselle, M. Stepnik, T. Vanhaecke, S. Wijnhoven, E. Benfentati, N. Cabaton, E. Corsini, A. Koutsodimou, H. Louro, W. Uter, N. von Goetz. *SCCS Notes of Guidance for the Testing of Cosmetic Ingredients and their Safety Evaluation 12th revision*, 15 May 2023, SCCS/1647/22. [https://health.ec.europa.eu/latest-updates/sccs-notes-guidance-testing-cosmetic-ingredients-and-their-safety-evaluation-12th-revision-2023-05-16\\_en](https://health.ec.europa.eu/latest-updates/sccs-notes-guidance-testing-cosmetic-ingredients-and-their-safety-evaluation-12th-revision-2023-05-16_en)
- SCCS (Scientific Committee on Consumer Safety), U. Bernauer, L. Bodin, Q. Chaudhry, P.J. Coenraads, M. Dusinska, J. Ezendam, E. Gaffet (Rapporteur), C. L. Galli, E. Panteri, V. Rogiers, Ch. Rousselle, M. Stepnik (Rapporteur), T. Vanhaecke, S. Wijnhoven, E. Benfentati, N. Cabaton, E. Corsini, A. Koutsodimou, H. Louro, W. Uter, N. von Goetz. *SCCS Scientific Advice on Titanium dioxide (TiO<sub>2</sub>) (CAS/EC numbers 13463-67-7/236-675-5, 1317-70-0/215-280-1, 1317-80-2/215-282-2)* - SCCS/1661/23. Adopted by written procedure on the 4th December 2023 Published on the 5th December 2023 (226 pages) and 3 joined Annexes [https://health.ec.europa.eu/publications/scientific-advice-titanium-dioxide-tio2-casec-numbers-13463-67-7236-675-5-1317-70-0215-280-1-1317-80\\_en](https://health.ec.europa.eu/publications/scientific-advice-titanium-dioxide-tio2-casec-numbers-13463-67-7236-675-5-1317-70-0215-280-1-1317-80_en)
- Valente A, Vieira L, Silva MJ, Ventura C. *The Effect of Nanomaterials on DNA Methylation: A Review*. *Nanomaterials (Basel)*. 2023 Jun 17;13(12):1880. doi: 10.3390/nano13121880. PMID: 37368308; PMCID: PMC10305477.

The **University of Aveiro** has published several papers on ecotoxicity for aquatic (freshwater and marine) and soil organisms, bioaccumulation and kinetics for soil and freshwater organisms, including:

- Campos, B. G., Kaczerewska, O., Oliveira, J. M. M., Figueiredo, J., Maia, F., Tedim, J., Sousa, I., Abessa, D. M. S., Loureiro, S., & Martins, R. (2024). *Multipurpose Fluorescent Nanocarriers: Environmental Behavior, Toxicity and Internalization on Marine Microalgae*. *Advanced Sustainable Systems*, 9(1). <https://doi.org/10.1002/adsu.202400378>
- Peixoto S, Morgado RG, Prodana M, Cardoso DN, Malheiro C, Neves J, Santos C, Khodaparast Z, Pavlaki MD, Rodrigues S, Rodrigues SM, Henriques I, Loureiro S. *Responses of soil microbiome to copper-based materials (nano and bulk) for agricultural applications: An indoor-mesocosm experiment*. *NanoImpact*. 2024 Apr;34:100506. doi: 10.1016/j.impact.2024.100506. Epub 2024 Apr 16.
- Ribeiro F, Pavlaki MD, Loureiro S, Sarmento RA, Soares AMVM, Tourinho PS. Systematic Review of Nano- and Microplastics' (NMP) Influence on the Bioaccumulation of Environmental Contaminants: Part II-Freshwater Organisms. *Toxics*. 2023 May 23;11(6):474. doi: 10.3390/toxics11060474.

- Tourinho PS, Loureiro S, Pavlaki MD, Mocová KA, Ribeiro F.A Systematic Review of Nano- and Microplastic (NMP) *Influence on the Bioaccumulation of Environmental Contaminants: Part I-Soil Organisms*. *Toxics*. 2023 Feb 7;11(2):154. doi: 10.3390/toxics11020154.

### 3.11 Switzerland

Switzerland contributed to the Guidance for Sample Preparation and dosimetry (GSPD) by drafting part of the in vitro section on submerged cell culture-based assays.

Furthermore, Switzerland is part of the Expert Group of OECD Project 4.174 “Validating the in vitro Micronucleus assay for Engineered Nanomaterials”.

### 3.12 Sweden

Researchers from IMM at Karolinska Institutet participate as delegates in the OECD WPMN steering group for Advanced Materials (SG-AdMa), and in the OECD Expert Group on Genotoxicity. In the case of SG-AdMa, contributions were made specifically to an online workshop on  $Ti_3C_2$  MXenes (May 2024) and a workshop on graphene-based materials at OECD in Paris (November 2024), as well as overall to the case studies on both MXenes and graphene-based materials. The Swedish expert in the OECD Expert Group on Genotoxicity supports the project “*Validating the In Vitro Micronucleus assay for Engineered Nanomaterials*”.

### 3.13 United Kingdom

#### 3.13.1 International Standardization Organization (ISO) Documents

HSE Science and Research Centre have led on the revision of ISO 12901 (Nanotechnologies on Occupational Risk Management applied to engineered nanomaterials Part 1: Principles and approaches) under ISO TC 229. The revision was finalized and published in 2024.

Standardization activities on graphene are ongoing with the National Physics Laboratory (NPL) leading work in relation to ISO TC 229 and having input into the following documents: Nanotechnologies — Structural characterization of graphene — Part 1: Graphene from powders and dispersions; Nanotechnologies — Structural characterization of graphene — Part 2: Graphene sheets on a substrate; Nanotechnologies — Classification framework for graphene-related 2D materials; Nanotechnologies — Chemical characterization of graphene-related two-dimensional materials from powders and liquid dispersions; and Nanotechnologies — Structural characterization of graphene oxide flakes: thickness and lateral size measurement using AFM and SEM.

#### 3.13.2 Committee for European Standardization (CEN) Documents

National Physics Laboratory (NPL) has been leading the development of CEN/TS “Nanotechnologies — Guidance on the determination of the agglomeration state and aggregation state of nano-objects”.

# 4 Information on any developments related to Integrated Approaches to Testing and Assessment (IATA) for NM/AdMa

## 4.1 Austria

Martin Himly, Head of the Bio-Nano Interactions Group at the Paris Lodron University Salzburg (PLUS), leads the WP for integration of industry needs in the HORIZON-2023-Resilience-01-23 project PINK which endeavours to establish an *in silico* hub for integrated SSbD-guided research and innovation of advanced materials. Here *in silico* tools will be aligned inter-operatively according to FAIR principles across different sustainability dimensions (health, environment, social, economic). The industry focus, driven through various industry-delivered case studies, should facilitate usability of the planned *in silico* hub, the so-called PINKISH platform, for SMEs and big industry and aid in SSbD-guided development.

The NMBP-16 projects DIAGONAL & HARMLESS, where BNN (contact: Susanne Resch) is part of the consortia, established a “NMBP-16 Ambassadors Group on grouping and read-across (incl. hypotheses and IATA editing/development)” together with their third sister project SUNSHINE, where different case studies from the projects related to multicomponent nanomaterials are studied. One result was the demonstration of the development of multi-dimensional similarity assessment methods that can be applied to multicomponent nanomaterials, applied for the case of core-shell quantum dots.

## 4.2 BIAC

**BIAC** through the **NIA** actively contributes to the discussion on Advanced Materials through its participation at the OECD WPMN Steering Group on Advanced Materials. The NIA has contributed to the further development of the Early4AdMa, through recommendations for improvement communicated in different workshops. The NIA is chair of the Uptake and Deployment subgroup of the EC’s Technology Council for Advanced Materials. This subgroup has submitted a number of recommendations which are due to be discussed at the upcoming Council meeting. These include recommendations around standards and regulations.

## 4.3 Croatia

Croatian experts from IMROH contributed to the development of regulatory-relevant guidance, addressing both human and environmental health prioritizing *in vitro* methods, based on an IATA framework. A freely

available Template Wizard (<https://doi.org/10.1038/s41596-024-00993-1>) for researchers to easily create templates suitable for consistently capturing data and metadata from their experiments related to the safety evaluation and regulation process for (nano) materials. The templates are easy to use and enable the compilation of machine-readable metadata to accompany data generation and align them to existing community standards and databases, such as eNanoMapper, streamlining the adoption of the FAIR principles. The templates are generalizable across fields and have already been extended and adapted for microplastics and advanced materials research. The harmonized templates improve the reliability of interlaboratory comparisons, data reuse and meta-analyses and can facilitate.

Research project ECHA/2022/502 - Lot 2 “Framework Contract for the development of NAM based tools and data for hazard identification and characterisation of industrial chemicals, including polymers and nanoforms.”, led by QSAR Lab from Poland is underway in the IMROH as partner institution. This project contributes and supports the development of NAMs for efficacy and safety assessment of nanomaterials and advanced materials, thus, supporting Integrated Approaches to Testing and Assessment (IATA).

#### 4.4 European Union

**EFSA** recently started a new multiannual project called NAMs4NANO (2023-2027, 5.3M). The project was granted to a large consortium involving several EU MSs and extra EU organisations, and includes a partnership with EC JRC. The main goal of this project is to promote the implementation of NAMs in the risk assessment of nanomaterials, and it is subdivided in three Lots (i.e. Lot 1: Review of NAM-based tools for nano-specific risk assessment & Develop a Qualification System for NAMs in EFSA using the experience from EMA & US FDA; Lot 2: Design and conduct a set of (5) case studies using NAM-based IATA to fill data gaps in nanomaterials risk assessment, covering regulatory areas within the EFSA's remit; Lot 3: Design and conduct a set of (5) case studies to improve NAM-based methodologies for nanospecific assessment). The first two Lots are led by BfR (Germany), and the third Lot by ISS (Italy). The first deliverable of this project is a ‘[Review of NAM-based tools for nano-specific risk assessment](#)’ and ‘[Proposal for a qualification system for New Approach Methodologies \(NAMs\) in the food and feed sector: example of implementation for nanomaterial risk assessment](#)’, which were published as External Report in the EFSA website.

EFSA launched two new outsourced activities aimed at promoting the implementation of New Approach Methodologies (NAMs) for nanoparticles risk assessment. Further information on the call for tenders is available at the following links in the EU Funding and Tender Portal:

- [Developing provisions for guidance on New Approach Methodologies \(NAMs\) data integration and implementing hypothesis-driven Next Generation Risk Assessment \(NGRA\), with specific focus on the area of food nanotechnology](#)
- [Integration of New Approach Methodologies in Chemical Risk Assessment: Case Studies Addressing Nanoplastics in Food \(NAMs4NANOPlastics\)](#)

ECHA has in the context of New Approach Methodologies (NAMs) launched a Multiannual Framework Contract (FWC) for the development of NAM-based tools: methodological developments and data generation for the assessment and grouping of sets of nanoforms. The objective was to justify that variations within the boundaries of a set of nanoforms do not affect the hazard assessment, exposure assessment, or risk assessment of similar nanoforms within the set using NAMs.

- A Specific Contract 1, running from May 2024 to May 2025, mapped the information on NAMs aiming at fulfilling the regulatory needs for sets of nanoforms to justify that a variation within the boundaries of the set of nanoforms does not affect the hazard, exposure and risk assessment of

the similar nanoforms in the set. The outcome this specific contract consisted in a complex inventory of NAMs (and, potentially useful, simpler ‘measurements’) already applied for TiO<sub>2</sub> nanoforms and carbon nanotubes. The inventory also included all international initiatives and projects, as well as NAMs under development identified as relevant. Finally, a draft NAM-based framework for setting the boundaries for sets of nanoforms was proposed. The presented concept of the draft NAM-based framework integrates physicochemical characterization and toxicity testing, aiming for a statistically verified, flexible, and regulatory-suitable approach.

The Specific Contract 2 was launched in June 2025 with the objective of developing the draft framework proposed under Specific Contract 1 and verifying its usability for setting boundaries for sets of nanoforms (nanoset) using a pilot case study.

## 4.5 Germany

### 4.5.1 German Federal Institute for Material Research and Testing (BAM)

BAM, UBA and 26 other partners finalized successful the EU-funded project “PlasticsFatE” (<https://www.plasticsfate.eu/>). The main topic was on refining key policy recommendations, standardisation efforts, and regulatory approaches for tackling the complex challenges posed by microplastics (MNPs). Exposure and hazard assessment, human and environmental health risks, industry collaboration, harmonisation of research methodologies, and public engagement are addressed. BAM has led a VAMAS interlaboratory comparison on Development of standardized methodologies for characterisation of microplastics with microscopy and spectroscopy methods

([https://www.vamas.org/twa45/documents/vamas\\_twa45\\_p2\\_MPs\\_microscopy\\_spectroscopy.pdf](https://www.vamas.org/twa45/documents/vamas_twa45_p2_MPs_microscopy_spectroscopy.pdf)).

For example, this could include information related to initiatives, workshops, publications. Whether these are based on new compositions, combinations of existing materials, materials with unique properties.

### 4.5.2 German Federal Institute for Risk Assessment (BfR)

The implementation of NAMs (New Approach Methodologies) in IATAs for risk assessment of nanomaterials in the food and feed sectors will be supported by the outcome of the EFSA-funded NAMs4NANO project (2023-2027). In addition, a risk assessment framework was recently published (see part 7, research activities) within the EU POLYRISK project (2021-2025) that also covers the development and application of IATAs in risk assessment.

The BfR is coordinating the German interagency working group between German higher federal authorities. The working group is continuing scientific exchange on the topic of advanced materials (e.g., nanocarriers, fibres, advanced materials for batteries, etc.).

The OECD Steering Group on Advanced Materials (SG AdMa) organised a joint online workshop (04/2025) in collaboration with the EU HARMLESS and EU SUNSHINE’s/SUNRISE projects to improve Tier 1 of the Early4AdMa warning system. The BfR, as a partner in the HARMLESS project, introduced HARMLESS EWS (Early Warning System) as a tool for pre-assessment of advanced materials in early stages of innovation. The applicability of the HARMLESS EWS workflow was further assessed by experts using data from the HARMLESS perovskite case study. The report of the workshop will be presented in the 25th WPMN meeting (06/2025) for further discussion of the next steps. A scientific publication on the HARMLESS EWS was recently published (<https://doi.org/10.1002/adsu.202500217>).

The 5th Symposium on Nanotechnology (05/2025), jointly organised by the BfR and the Fraunhofer Nanotechnology Network (FNT), deals with the exchange on opportunities and risks of nanomaterials and

advanced materials in various sectors such as digitalisation, 2D/3D printing, carbon-based materials and battery materials. A report of the symposium will be published.

### 4.5.3 Federal Ministry of Education and Research (BMBF)

Advanced Materials are a strategic priority for Germany. Since more than 30 years the German Ministry of Education and Research (BMBF) is supporting high level research projects in materials science with dedicated funding programs. In January 2025, BMBF has published its new funding program “Material innovations for transforming economy and society (Mat2Twin)” that is setting the funding priorities in materials science for the next years. Three main topics have been identified: digitization of materials research, resource efficiency and sustainability and “biologization” what means to apply principles found in nature to materials research. An English version of the program will soon be published under <http://www.werkstofftechnologien.de>. Safety aspects will be considered in all funding activities. The entire life cycle of materials and the products that are subsequently made using them are taken into account.

The almost simultaneous launch of Mat2Twin and the EU Initiative “Advanced Materials for Industrial Leadership (AM4IL)” will be used to create program links between national and EU funding. The BMBF is supporting the creation of a European digital infrastructure for AM (the “Materials Commons”) through which a European digital infrastructure for AM is to be established, under the framework of Horizon Europe. The BMBF supports these efforts and will provide the preparatory work and specialist knowledge gained from the national funding activity “MaterialDigital” as a focal point for the development of the Materials Commons.

## 4.6 Italy

In the NAMs4NANO action, hypothesis-driven IATAs are used within several case studies covering food-related applications, each focusing on a different material type, to address nano-specific questions and guide the hazard assessment. Oral exposure is the main scenario covered, but within specific case studies (e.g. the nanocarrier pesticide case study) also the dermal and inhalation exposure routes are dealt with. NAM-based approaches are being used to generate de novo data, which are being integrated with evidence in the literature or from other projects and assessments. The hypotheses underlying the IATAs mainly link the particle durability and biopersistence (i.e. dissolution kinetics) to specific hazard outcomes. Preliminary results are being gathered, final ones are expected in 2026.

## 4.7 The Netherlands

RIVM is part of the NAMS4Nano project that is procured by EFSA. The project aims to **gain experience with New Approach Methodologies (NAMs) for nanomaterials**. This includes e.g. the bridging of information to non-nanomaterial counterparts. For various materials Integrated Approaches for Testing and Assessment (IATAs) are being developed to assess relevant questions in risk assessment. For other materials more general considerations are investigated. RIVM is (co-)chair for nanosilver, nanofibres and simple organism models. The project spans 4 years and started in April 2023. Led by BfR, a review on available NAMs that are potentially useful for risk assessment on nanomaterials has been published (Usmani et al., 2024, doi: [10.2903/sp.efsa.2024.EN-8826](https://doi.org/10.2903/sp.efsa.2024.EN-8826)), as well as a proposal for a qualification system for NAMs (Haase et al., 2024, doi: [10.2903/sp.efsa.2024.EN-9008](https://doi.org/10.2903/sp.efsa.2024.EN-9008)). In the latter, a process for qualification is outlined, in which the scientific validity, i.e. its reliability and relevance for the context-of-use, needs to be demonstrated. This aims to facilitate the regulatory use of NAMs for a specific context.

## 4.8 Portugal

Portugal, through the **National Institute of Health** (INSA, Lisbon, Portugal), develops research in new approach methodologies, in the field of the Adverse Outcome Pathways (AOPs) framework proposed by OECD and integrated approaches for safety assessment (IATAs) to apply to ingested nanomaterials such as titanium dioxide and nanocelluloses (nationally funded projects by Portuguese Foundation for Science and Technology) with publication of several scientific papers, such as:

- Rolo, D, Tavares A, Vital N, Silva MJ, Louro H. *Overview of Adverse Outcome Pathways and Current Applications on Nanomaterials*. *Rolo Adv Exp Med Biol*. 2022;1357:415-439. doi: 10.1007/978-3-030-88071-2\_17.
- Rolo D, Assunção R, Ventura C, Alvito P, Gonçalves L, Martins C, Bettencourt A, Jordan P, Vital N, Pereira J, Pinto F, Matos P, Silva MJ, Louro H. *Adverse Outcome Pathways Associated with the Ingestion of Titanium Dioxide Nanoparticles-A Systematic Review* *Nanomaterials* (Basel). 2022;12(19):3275. doi: 10.3390/nano12193275.
- Vital N, Gramacho AC, Silva M, Cardoso M, Alvito P, Kranendonk M, Silva MJ, Louro H. *Challenges of the Application of In Vitro Digestion for Nanomaterials Safety Assessment*. *Foods*. 2024 May 28;13(11):1690. doi: 10.3390/foods13111690.

## 4.9 Switzerland

Switzerland has nominated experts from five Swiss research institutions to support the OECD group's work on the safety testing of nanoplastics:

- Agroscope (the Swiss Confederation's centre of excellence for agricultural research)
- EAWAG (the Swiss Federal Institute of Aquatic Science and Technology)
- the University of Fribourg
- the Ecotox Centre Switzerland
- ETHZ (the Federal Institute of Technology Zurich)

## 4.10 United Kingdom

### 4.10.1 NanoSolveIT

This project will develop and deliver a validated, sustainable and multi-scale nanoinformatics IATA, tested and demonstrated via OECD style IATA case studies for assessment of potential adverse effects of nanomaterials on human and environmental health. The innovative nanomaterial fingerprint approach developed will be the core of the model integration, supporting the IATA by linking laboratory characterization data, computational characteristics, biological signatures and image analysis. This project is coordinated by Novamechanics with the University of Birmingham in the UK.

# 5 Developments and/ or considerations related to “advanced” materials (multicomponent / complex)

## 5.1 Austria

As a measure of implementation of the Austrian Nanotechnology Action plan the national NANO Environment Health and Safety programme (NANO EHS, <https://www.ffg.at/programme/nano-environment-health-and-safety>) has been established. In the 10th NANO EHS call for proposals in 2023, the project AdMa4Med (“Advanced Materials and Nanomaterials for Medical Application”; coordinated by BNN (contact: Andreas Falk)) was funded. This project investigated the use of nanomaterials (NM) and advanced materials (AdMa) in medical devices and associated opportunities and challenges. These innovative materials offer great potential for improved functionalities, but raise regulatory, safety and sustainability-related questions. Based on a comprehensive literature review on the state of the art and qualitative expert interviews with various stakeholders along the value chain of medical device R&D&I, recommendations were formulated on what needs to be done to accelerate the adoption of NM and AdMa in medical devices while ensuring its safety, sustainability and regulatory compliance. Therefore, a matrix for preparing for regulatory compliance and preparing for sustainability was developed, providing researchers, developers and innovators with a guideline to be taken into account from the early stages of innovation.

The national Nano-EHS project CERANANO (BOKU University, lead: Prof. Dr. Eva-Kathrin Ehmoser and Anna Pavlicek MSc. MSc.) was completed at the end of 2024. This project focused on the nano-level analysis of ceramic dental implants, which are a promising alternative to traditional titanium oxide implants. The project had three main objectives:

First, to conduct a thorough literature review on the current state of the art, including the advantages and disadvantages, as well as safety and application issues of ceramic implants compared to titanium oxide implants.

Second, to collect and synthesize the opinions and experiences of experts from various fields related to dental implantology—such as dentists, implant manufacturers, and other relevant stakeholders—through an online survey.

Third, within the scope of CERANANO, an experimental series was conducted using human osteoblast cells (HOB-c) to examine the morphology, behavior, and inflammatory effects of ceramic nanoparticles that may result from the abrasion of ceramic implants. The project employed high-resolution microscopy and cytokine assays to visualize and quantify the interaction of ceramic nanoparticles with living cells and compared the results with particles made of titanium oxide.

The national Nano-EHS project SAMA (Sustainability aspects of Advanced Materials in digital technologies in Agriculture) started in January 2025 and is coordinated by BOKU University (Anna Pavlicek). In

cooperation with the ZSI (Centre for Social Innovation) and on the basis of two practical examples from company partners (Mechatronik Austria GmbH, SoilMap) the project aims to evaluate the sustainability aspects, opportunities and risks of 'advanced materials' in digital devices for agriculture and to develop proposals for more environmentally and socially compatible development in line with the 'safe and sustainable by design' concept. (<https://forschung.boku.ac.at/en/projects/16220>)

CERANANO provided a comprehensive and up-to-date overview of the nano-level aspects of ceramic dental implants. The project also contributed methodologically to addressing existing knowledge gaps regarding nanomaterials in dental implantology and supported the safety and application assessment of ceramic implants, which are expected to grow in demand and popularity in the future.

The Austrian Erwin Schrödinger Society of Nanosciences (ESG) organized an international conference on the topic FEMTOMAT, which focuses on laser-based characterization of advanced materials (AdMa), primarily at the nanoscale. This conference is supported by the Ministry of Innovation, Mobility and Infrastructure (BMIMI) and takes place on a biannual basis at Burg Mauterndorf, Austria. Around 60 participants presented their work, engaged in discussions, and initiated collaborations. Novel approaches and methods were presented on how to manipulate, integrate, and convert materials at their interfaces, preferably by optical means.

The organizing team includes Dr. Aida Naghilou (Medical University of Vienna), em. Prof. Dr. Wolfgang Kautek (University of Vienna), Dr. Oskar Armbruster, and Prof. Dr. Eva-Kathrin Ehmoser (both from BOKU University). Further details regarding the content of the respective talks can be found on [www.esg-nano.ac.at](http://www.esg-nano.ac.at), along with the book of abstracts.

In autumn 2024, answering the 11th NANO EHS call for proposals, the projects PHASE5 ("Integration sozialer Aspekte in SSbD-Entwicklungen am Beispiel der Pharmaindustrie"; coordinated by BNN (contact: Andreas Falk)) and SESAM ("Social and Economic impactS - A practical assessMent in the ssbd framework"; coordinated by JOANNEUM RESEARCH POLICIES in collaboration with Brimatech and BNN (contact: Susanne Resch)) were kicked-off. Both projects address the implementation of the JRC Safe-and-Sustainable-by-Design concept during the development of AdMa, in particular the socio-economic evaluation (Step 5). PHASE5 aims to develop a recommendation for action for the improved implementation and evaluation of SSbD and its Step 5 in the context of AdMa in the pharmaceutical industry, while SESAM provides for the practical testing of the SSbD Step 5 using functional, doped ZnO nanoparticles. As part of the practical testing with real data, the extent to which the concept of sLCA is suitable for successfully implementing Step 5 of the SSbD framework with reasonable effort for SMEs will be tested. In March 2025, the NANO EHS project PEARL-Mat ("PErspektive, Anwendungen und Richtungsweisung für engineered Living materials und 2D/2D+HybridMATERialien"; coordinated by AC2T in collaboration with BNN (contact: Susanne Resch)) was kicked-off. 2D/2D+ hybrid materials (HD) represent a promising development of 2D materials. Recently, the huge potential of engineering living materials (ELM) has been also recognized for the realization of smart and highly functional systems, e.g., in combination of 2D materials as well too. Nowadays, it is very challenging to obtain a state of the art and fully objective overview on these two categories of materials, namely 2D/2D+ hybrid materials (HDs) and ELMs, what concerns their synthesis, controlled unique features, tuneable functionalities, toxicity, environmental impacts, their supposed or at least in laboratory demonstrated utility across various fields of application, and ultimately their upscaling into industrial products. The PEARL-Mat project aims to provide an up-to-date and widely complete knowledge map of both 2D/2D+ HDs and ELMs with respect to all their ever-mentioned facets, and on this basis also to identify knowledge gaps, potentials and opportunities for the Austrian scientific community and industry. To achieve this ambitious goal, PEARL-Mat combines the bibliographic analysis with advanced semantic tools, which are commonly used as prerequisite techniques for founding various ontologies. Furthermore, PEARL-Mat will perform expert interviews and will organize at least one stakeholder workshop on national (Austria) and international level. Finally, PEARL-Mat will make an attempt to validate a few carefully selected outcomes and findings of the

considered methodology by estimating their realization probability via some proper AI techniques, like machine learning methods.

In addition to the NanoEHS scheme, the Austrian government called for “mobilizing and networking” activities with a specific topic to create one thematic community in Austria, that covers all relevant stakeholders in the countries area of Advanced/innovative Materials (AdMa). The project ATIMA (“Mobilisation and connection of national stakeholders on the topic of ‘Advanced & Innovative Materials’ in Austria”) runs from November 2024 till October 2026 and is coordinated by BNN (contact: Andreas Falk). ATIMA promotes the exploration, networking, and mobilization of future-relevant materials and technologies. Through strategic collaboration across disciplines and the creation of unique interfaces, the project fosters synergies that strengthen Austria’s innovation capabilities while developing new technologies and essential skills. ATIMA actively supports innovation and lays the foundation for economic, scientific, and societal advancement. It will become the main connecting point with European initiatives e.g., IAM-I association, etc.

The European Commission selected in the 2024-call “Synergy with national and regional initiatives in Europe on Innovative Materials (CSA)” the project InnoMatSyn (“Innovative Materials Ecosystem to Gain Synergies of Regional, National and EU Initiatives”), which runs from March 2025 till February 2028 and is coordinated by BNN (contact: Andreas Falk). InnoMatSyn aims to support and catalyse coordination of Innovative Advanced Materials stakeholders, funding bodies and initiatives at national and regional levels across Europe. The project will provide an interconnected materials ecosystem, AI-based knowledge repository, technology leakage risk assessment, and support for joint funding calls.

## 5.2 BIAC

As a partner of the OECD SG AdMa, **BIAC** through the **NIA** takes part in these discussions, looking into safety and sustainability of the different case studies, which is essential in the scope of future policy developments.

## 5.3 Canada

Agriculture and Agri-Food Canada (AAFC) is undertaking a research project which focuses on developing advanced materials for improving detection of viruses and bacteria. This work is using molecular self-assemblies to coat 3D objects. The microbial biocapture is validated using viruses.

The Canadian Food Inspection Agency (CFIA) also has a project to develop material prototypes with immobilized nanoparticles as a tool to determine the impact of using them as antiviral coatings (published recently : Raymond et al., *Foods* **2024**, 13, 1527. <https://doi.org/10.3390/foods13101527>).

## 5.4 Croatia

The IMROH leads Work Package 5 of the HORIZON EUROPE project “NABIHEAL – Antimicrobial Nanostructured Biomaterials for Complex Wound Healing” (start: January 2023) aims to develop multifunctional biomaterials to improve wound management, by using quatsomes nanovesicles with demonstrated inherent antimicrobial properties as alternative to silver. This WP is focused on safety testing of advanced materials.

## 5.5 The Netherlands

The **European project MACRAMÉ** is aligned with the EU ambitions to secure the safety and sustainability of new chemicals, materials, products and processes in order to strive for zero pollution and toxic-free environments. The project concentrates on **methodologies that are applicable to nanomaterials and widens them to advanced materials in commercialised products**. A recent publication (doi: [10.1016/j.csbj.2025.03.032](https://doi.org/10.1016/j.csbj.2025.03.032)) summarises the important impact the project will have by integrating knowledge from major European and international initiatives to establish harmonised test guidelines, guidance documents, and standards. Within the project, RIVM will use air liquid interface (ALI) models developed and used within previous EU projects to assess potential hazard of the selected advanced materials after inhalation. Both deposition of a dispersion, and two options for dry exposure will be used, for difficult to disperse materials (e.g. graphene). To advance the best models towards OECD test guidelines and standards, there will be an exchange of ALI models among laboratories. As co-lead of WP1 on Bridging Communities & Refining MACRAMÉ Strategies RIVM in collaboration with MACRAMÉ partners provided a “gap analysis” to specify the regulatory needs for advanced materials with a focus on their assessment throughout the life cycle. This forms an important basis for a series of recommendations by MACRAMÉ to be discussed in a [Joint Regulatory Risk Assessors Summit](#) (with EU projects iCare, nanoPASS, ACCORDs) in June 2025 at the OECD.

The European project InnoMatSyn (Innovative Materials Ecosystem to Gain Synergies of Regional, National and EU Initiatives) started March 2025 and aims to support and catalyse the coordination, and mobilisation of the Innovative Advanced Materials stakeholders, funding bodies and initiatives at national and regional level. This aims to drive and push Europe’s national and regional actors towards complementarity and synergy. InnoMatSyn is building on regions existing smart specialisation, that strengthens the regions within the European collaboration. The project will provide the following outcomes: (i) an interconnected materials ecosystem, (ii) a dynamic Artificial Intelligence (AI) based knowledge repository, (iii) a technology leakage risk assessment strategy and guidance, and (iv) support to national and regional funding bodies in terms of strategies and content for joint national and European calls and other interregional initiatives. It will create a knowledge overview, identify gaps/needs of the field and engage funding bodies to address these. It aims to support member states with guidelines for implementing the technology leakage risk assessment strategy. In addition, synergies will be created among existing materials initiatives and a common strategy developed to ways forward, including interaction with and support to funding bodies and partnerships. The main aim of RIVM’s participation in the project is to ensure inclusion of safety and sustainability (by design).

## 5.6 Portugal

The **University of Aveiro** has research on multicomponent nanomaterials, modelling and predicting, while testing using mixture toxicity approaches, having published papers on these topics (e.g. DOI: 10.1016/j.scitotenv.2016.11.095; DOI: 10.1016/j.jhazmat.2016.07.068).

The CeNTI - Centre for Nanotechnology and Advanced Materials (Vila Nova de Famalicão, Portugal), is involved in multiple research projects, including:

- BIOMAT- established the BIOMAT-TB, an Open Innovation Test Bed to support industries and SMEs by fostering cross-border collaboration and accelerating innovation in nano-enabled, sustainable bio-based materials. These cutting-edge materials target applications in the building & construction, automotive, and furniture & bedding sectors. Since July 2024, the following publication highlighted the use of these innovative nanomaterials:
  - Pinilla-Peñalver, E.; del Fresno, Ó.; Cantero, D.; Moreira, A.; Gomes, F.; Miranda, F.; Oliveira, M.; Ornelas, M.; Sánchez-Silva, L.; Romero, A. Gels, 10 (2024), 465. Enhancing

Flame-Retardant Properties of Polyurethane Aerogels Doped with Silica-Based Particles  
<https://doi.org/10.3390/gels10070465>

- Bengalli, R.D.; Gualtieri, M.; Ornelas, M.; Tzanov, T.; Mantecca, P., *Nanomaterials* 15 (2025), 549 Adverse Outcome Pathways (AOPs) Oriented Approach to Assess In Vitro Hazard of Silica and Lignin Nanomaterials Derived from Biomass Residues. <https://doi.org/10.3390/nano15070549> (registering DOI)
- PRIMED project - to redesign the primary sector for maximizing bioeconomy development by converting bio-waste into bio-based products that can be used in multiple applications. One of those Living Labs – the Bio-Silica Lab, is located at CeNTI and is focused on the extraction of bio-based silica nanoparticles from agroindustrial waste.
- BIONANOPOLYS project aimed to create an Open Innovation Test Bed (OITB) with cross-cutting technologies dedicated to transform biomass into sustainable nanomaterials of industrial interest, to accelerate its introduction and adoption by the market, and boost the nanotechnology based on raw materials of biological and sustainable origin in Europe. CeNTI's role was fundamental as its pilot plants covered most of the value chain, from the raw material transformation into functional additives, to the functionalization of substrates, and contributed to the reduction of human and material costs in each trial through a set of diverse upgrades.
- InComEss project, new green and cost-effective strategy for highly efficient energy harvesting by combining new smart advanced polymer-based composite materials and structures into a single/multi-source concept to harvest electrical energy from mechanical energy and/or waste heat ambient sources, which consists of three novel Energy Harvesting Systems (EHSs) configurations: Piezoelectric, Thermoelectric and hybrid Thermo/PiezoElectric EHSs. Similarly, the Automotive use-case results demonstrated the reliability of the Wireless EHS.
- The Innovation Pact from “Fossil To Forest” aims the development of cellulose-based packaging and products to replace current fossil-based plastics, with a particular focus on food sector. In this scope, improved paper solutions are being developed, as well as biocomposites, from which new packaging products will emerge.
- The HfPT – Health from Portugal agenda aims to position Portugal as a world reference hub in the design, development, and production of advanced solutions, based on innovation and technology, for health markets. Within the focus areas of this agenda, WP2 - A2 Biomaterials and Nanomedicine aims to meet the unmet needs of carers, chronically ill patients and the general population through the development of innovative products that can be incorporated into the value chain of medical devices and medicines, promoting their placement at the forefront and reference level in the health area, positioning them to respond to demand in the global market. Furthermore, ‘PPS A2.1 - Development of advanced systems for controlled drug delivery through topical and transdermal application’ aims to develop a set of advanced systems for the controlled release of bioactive agents, bio-based, by topical application, which will result in products, such as functional textile structures and bioactive dressings for the treatment of acute and chronic wounds, as well as the co-adjuvant treatment of chronic diseases, such as diabetic foot ulcers. CeNTI's role consists of the encapsulation of antimicrobial and anti-inflammatory compounds to achieve a controlled release when applied in dressings and textile substrates, as well as the development of functional coating formulations for application on textile substrates, which active functionalities could last over 20 washing cycles.
- The NanoTheC-Aba project was developed for ensuring clean and safe water from sources contaminated by pathogens and toxic organic compounds, which originate from natural processes or anthropogenic activities such as hospital effluents, industrial discharge, aquaculture, and black/white waters. In the project, CeNTI played a key role in substrate functionalization and the development of innovative materials for filtration membranes. Among its main contributions, CeNTI was responsible for the development and characterization of nanostructured materials, including SiO<sub>2</sub>@TiO<sub>2</sub> (core-shell), carbon nitride (g-C<sub>3</sub>N<sub>4</sub>), and ZnO nanoparticles. These materials were

extensively studied in terms of morphology, composition, surface area, and crystallinity. Furthermore, their antimicrobial activity and ecotoxicological effects were assessed in the Aniene River, revealing their impact on microbial communities.

- The RN21 Integrated project – Innovation in the Natural Resin Sector for the Reinforcement of the National Bioeconomy, is divided in three main pillars, specifically at Pillar II2 - New Applications and Market Expansion, it brings together companies and scientific institutions to develop new applications and market niches for gum rosin and its derivatives in the food sector, particularly in materials and packaging (Pillar II2, 1A). The project focuses on leveraging the technical properties of natural rosin resin extracted from pine trees to develop innovative and sustainable solutions, ensuring their effective application across the value chain. CeNTI plays a pivotal role in the development of nanocoatings for biopolymeric films to be used in food packaging. While gum rosin-derived resins are incorporated into the polymer matrix of these films, the coatings themselves are based on other functional materials. By employing sustainable and waterless technologies such as atmospheric plasma coating, spray coating, and physical vapor deposition (PVD), CeNTI enhances the barrier properties of these films against oxygen and water vapor, critical factors in food preservation. These nanocoatings aim to improve packaging performance while maintaining environmental sustainability.

In addition to the above-mentioned activities, it is recognized that several public and private companies in Portugal investigate advanced materials and nanomaterials for multiple biomedical and industrial applications, such as **i3S** (Instituto de Investigação e Inovação em Saúde, University of Porto, Porto, Portugal) and others.

## 5.7 Switzerland

Two Empa laboratories are active partners in the EU project Macramé. Researchers contribute by providing advanced in vitro models and expertise for inhalation toxicology as well as by combining probabilistic environmental risk assessment with life cycle assessment.

In collaboration with Epithelix SA and the Cantonal Hospital St. Gallen, data on advanced materials' safety are generated based on air-liquid interface exposure of reconstituted bronchial and alveolar airway epithelium. Furthermore, and among other activities, researchers will investigate how in vitro data can substitute in vivo data for AdMa risk assessment. A modelling pipeline will be provided to enable predictive modelling of AdMa hazards based on in vitro data.

Selected publications:

- Gupta, G. et al., 2024, Small, 20, 2308148, doi: 10.1002/sml.202308148
- Wu, J. et al., 2024, NanoImpact 36, 100533, doi: 10.1016/j.impact.2024.100533

## 5.8 United Kingdom

### 5.8.1 Health and Safety Executive Advanced Materials project

This is a national project which aims to understand occupational risks to health from exposure to carbon-based materials, including composite materials and graphene, used in new manufacturing processes. NPL leading and contributing to the development of ISO documents for the characterisation of graphene and graphene platelets. This is an ongoing project focussed on workplace settings. The Health and Safety Executive Science Division is now working closely with the University of Manchester in this area.

### **5.8.2 UK Advanced Materials Workshops and Publication**

The UK previously held two Advanced Materials workshops. The first meeting included perspectives from organisations developing advanced materials, businesses manufacturing and using advanced materials, academics and regulators. The second meeting built on the first and focused on safety by design and life cycle analysis and included perspectives of challenges faced from different points in the supply chain. A paper *Safe and sustainable development of advanced materials: UK National Knowledge Sharing Network Workshops* was published in January 2025 outlining the highlights.

# 6 Developments in policy context for Advanced Materials

## 6.1 Austria

In 2024, Martin Himly from PLUS and Andreas Falk from BNN participated in drafting the roadmap towards Safe and Sustainable Advanced and Innovative Materials, which was drafted a joint endeavour of the steering team of the [NSC-Community](#) (formerly known as the EU NanoSafety Cluster). The document is available [here](#) and large industries, governments and policy, and other organisations active and interested in safety and sustainability of advanced materials, nanomaterials, and related processes and products.

## 6.2 BIAC

As part of the MALTA Initiative, EFSA Stakeholder Group on Emerging Risks, expert under the NMEG. on behalf of its members, the **NIA** has provided comments to the European Commission (both directly and also through the NSC), to the Technology Council for Advanced Materials, EFSA and other stakeholders on the lack of funding in the first and upcoming Horizon Europe Work Programmes to help support developing future Test Guidelines. The NIA has also consistently linked this issue to the broader policy and regulatory debate (e.g. revision of the REACH or Cosmetic Products Regulations, implementation of the Safe- and Sustainable-by-Design Framework), noting how nano-adapted TGs will be essential to facilitate compliance as well as to ensure the sustainability transition of European industry.

The NIA has also been participating in the International Network Initiative on Safe and Sustainable Nanotechnologies (INISS-nano), aimed at fostering global collaboration in areas of relevance to nanomaterials including standardisation and TGs development.

## 6.3 European Union

Announced in the 2024 [Communication on Advanced Materials for Industrial Leadership](#), a Technology Council was advanced materials has been set will the objectives to identify strategic goals and investment priorities for relevant research and innovation, align efforts at the European, national, and regional levels and outline initiatives to accelerate the deployment of advanced materials. It had met twice until July 2025; progress can be followed [here](#).

## 6.4 Germany

### 6.4.1 German Environment Agency (UBA)

Colleagues of UBA provided an opinion on safe and sustainable material innovation at ECHA's European Union Observatory for Nanomaterials: <https://euon.echa.europa.eu/de/nanopinion/-/blogs/ensuring-safe-and-sustainable-material-innovation-in-the-light-of-the-eu-communication-on-advanced-materials-for-industrial-leadership>

The "nanopinion" highlights the potential of advanced materials for areas such as the energy transition, sustainable mobility concepts or health protection, but also the challenges they might pose. In the opinion, it is argued that while the 2024 EU communication on Advanced Materials for Industrial Leadership stresses the relevance of advanced materials to achieve the goals of the EU Green deals, it still lacks concrete measures to ensure the safety and sustainability of advanced materials. Two key elements to enable safe and sustainable advanced materials are presented in the opinion: regulatory preparedness and safe and sustainable by design.

## 6.5 Sweden

### 6.5.1 Policy platform for advanced materials

A Swedish [platform focused on advanced materials](#) has been initiated by several innovation programmes and led by Chalmers Industriteknik. The work on an initial Swedish roadmap has been started (see further details above under the section National developments on human health and environmental safety).

### 6.5.2 InnoMatSyn

Chalmers Industriteknik and RISE are taking an active part in the EU-project [InnoMatSyn](#). The project aims to support and catalyse the coordination and mobilization of the Innovative Advanced Materials stakeholders, funding bodies and initiatives at national and regional level, to drive and push Europe's national and regional actors towards complementarity and synergy.

## 6.6 The Netherlands

With Germany as chair, the Netherlands co-chairs the **OECD WPMN Steering Group on Advanced Materials (AdMa)**. Regular meetings were organised in which the activities were presented and discussed with the experts. In May 2024, the Netherlands chaired a workshop on **MXenes**, as a case AdMa. Information on MXenes was gathered within a core group before the workshop and applied to the Early4AdMa system (doi: [10.1787/326fb788-en](https://doi.org/10.1787/326fb788-en)), which aims to address Regulatory Preparedness and Safe-and-Sustainable-by-Design of AdMa. The findings were presented to and discussed within the workshop with a broader audience. Ultimately facilitating timely identification of potential safety and/or sustainability issues of AdMa, and whether current regulatory frameworks and test methods are adequate. The findings of the assessment and workshop have been summarised into a draft-workshop report and developed further, trying to bring relevant follow-up actions into practice. Furthermore, experts from the Netherlands contributed to the Graphene Workshop (November 2024) and the Early4AdMa Tier 1 Workshop (April 2025), as organised by the OECD SG AdMa in collaboration with other partners.

# 7 Research programmes or strategies designed to address human health and/ or environmental safety aspects of (advanced) (nano) materials

## 7.1 Austria

The project "Examination and further development of strategic approaches for dealing with novel materials in chemical safety - study on nanocarriers and their environmental behaviour" is being carried out by BOKU University (contact Bernd Giese or Florian Part) started and will run from September 2022 until December 2025. It is commissioned by the German Environment Agency (UBA), project number (FKZ) 3722 66 401 0, and financed by the German Federal Ministry for the Environment, Nature Conversation, Nuclear Safety and Consumer Protection (BMUV). A literature review was conducted to identify types of nanocarriers that could be considered, among other things, for applications in agriculture and may pose previously undetected environmental risks. A working definition and systematic categorisation of NCS was elaborated and published (<https://doi.org/10.1186/s12951-025-03113-7>). Three different nanocarrier types were selected and tested on their potential mobility under different environmental conditions. The OECD Test No. 318 served as a starting point for testing the dispersion stability in simulated environmental media. One question that arises is whether this test is suitable for obtaining information about possible mobility. Further endpoints, such as the release of active ingredients and degradability of the nanocarrier, will also be investigated. A stakeholder workshop will be organised in Vienna on 5 November 2025 to discuss the project results and results from similar nanocarrier projects to identify research needs and necessary adaptations to the OECD Technical Guidelines.

In 2024, Martin Himly from PLUS and Andreas Falk from BNN participated in drafting the roadmap towards Safe and Sustainable Advanced and Innovative Materials, which was drafted a joint endeavour of the steering team of the [NSC-Community](#) (formerly known as the EU NanoSafety Cluster). The document is available [here](#) and large industries, governments and policy, and other organisations active and interested in safety and sustainability of advanced materials, nanomaterials, and related processes and products.

## 7.2 BIAC

**BIAC** through the **NIA** contributes to the development of SSbD strategies through its participation at EU initiatives such as Desiderata and the WPMN SG on Safer Innovation Approach, where NIA actively participates in the tools and platforms and Trusted Environments tasks. The NIA collects and shares information with its members at dedicated webinars and through surveys. In this reporting period we

collected from members their views on the Early4AdMa scheme as well as on Trusted Environments in collaboration with the EU projects SUNSHINE, SUNRISE and HARMLESS.

The NIA has also been involved in the ongoing European Commission and JRC's work on the development of SSbD criteria for the chemicals sector, providing comments as requested by the JRC on the adaptability of the proposed framework to nanomaterials.

## 7.3 Canada

### 7.3.1 Listing of internally funded projects undertaken by Environment and Climate Change Canada on engineered nanomaterial (ENM) including environmental toxicity testing and fate studies

Research on the fate and bioavailability of nanomaterials in the terrestrial environment:

- The influence of soil type (i.e., varying pH, organic matter content, clay content, etc.) on copper oxide (CuO) nanomaterial solubility and dispersity (10 nm, uncoated and coated (stearic acid, PVP)) was investigated using ten field soils. An extraction method was developed and optimized across the different soils to measure dissolved Cu, dissolved-complexed Cu, nanoparticulate Cu and residual/bulk phases. An empirical model was derived to predict, based on soil properties, soil environments that might pose greater ecotoxicological risk, based on CuO nanomaterial solubilization and nanoparticulate dispersity. Results indicate that soil pH has the greatest influence on CuO nanomaterial solubility/dispersity behaviour. The model is currently being verified using screening-level phyto- and microbial-based toxicity assays.
- Most recently, the effects of nickel oxide (NiO) nanomaterials are being investigated using a suite of soil tests including earthworm (*Eisenia andrei*) and springtail (*Folsomia candida*) reproduction, phytotoxicity and, microbial-based toxicity assays. The fate and toxicity of the NiO nanomaterials will be compared against bulk NiO and soluble Ni (NiSO<sub>4</sub>) at environmentally-relevant to higher (e.g., 1000 mg Ni kg<sup>-1</sup> soil) concentrations.
- The uptake and effects of micro- and nanoplastics from agricultural soils amended with biosolids to soil invertebrates and plants are also being investigated. Initial work has focused on the extraction and characterization of small micro (< 20 µm) to nano (<1 µm) scale plastics from biosolid and soil matrices as well as earthworm and plant tissues.
- Publications:
  - Samarajeewa A, Velicogna J, Schwertfeger D, Meier M, Subasinghe R, Princz J, Scroggins R, Beaudette L. 2023. Cerium oxide nanoparticles (NCeO<sub>2</sub>) exert minimal adverse effects on microbial communities in soils with and without biosolids amendment. *Environmental Science and Pollution Research*. <https://doi.org/10.1007/s11356-023-27313-6>
  - Schwertfeger DM, Velicogna JR, Chen H, Daymond S, Scroggins R, Princz JI. 2024. Comparing toxicities of nano cerium oxide and cerium nitrate to the soil invertebrates *Eisenia andrei* and *Folsomia candida* in a sandy loam, with and without biosolids. Submitted.
  - Abdulsada ZK, Kibbee R, Princz J, Ormeci B. 2025. Impact of silver and copper oxide nanoparticles on anaerobic digestion of sludge and bacterial community structure. *Nanomaterials*. <https://doi.org/10.3390/nano15030236>

### 7.3.2 Listing of projects undertaken by Health Canada and other partners to inform human health risk assessment of nanomaterials.

Health Canada's Environmental and Health Sciences Research Bureau (EHSRB) Exposure and Biomonitoring Division has laboratory research projects underway to develop strategies for rapid sample scanning for the identification of nanoparticles (NPs) containing potentially harmful transition metals and metalloids present at trace concentrations in environmental samples. A multi-element single particle inductively coupled plasma mass spectrometry (SP-ICP-MS) method has been optimized to identify metal(loid)s predominantly associated with NPs in house dust samples and quantify their number and mass concentrations. The test samples originate from the nationally representative Canadian House Dust Study. Research in collaboration with the University of Montreal is also investigating a complementary approach based on single particle inductively coupled plasma time-of-flight mass spectrometry (SP ICP-ToF-MS) to identify associations between different elements and quantify the single-element vs. multi-element NPs in house dust samples. In another study (Mechanistic Studies Division), researchers assessed particle uptake in Zebrafish larvae after exposure to different metal oxides using Enhanced Darkfield Hyperspectral Microscope and showed that metal oxide nanoparticles are sequestered in gill arches and intestine of the larvae. Other studies are developing New Approach Methodologies to assess toxicity, including tissue printing techniques.

In vitro toxicity testing for nanoforms of inorganic oxides

- The EHSRB Mechanistic Studies Division conducted work on well-characterized nanoforms of different inorganic oxides, including pristine at different sizes and surface-modified forms, testing *in vitro* cytotoxic potencies using multiple cell types. Multiple cytotoxicity assays as well as cell morphology analysis are also being carried out. The nanoparticles (NPs) being studied include nano TiO<sub>2</sub>, nano SiO<sub>2</sub>, nano ZnO, nano CeO<sub>2</sub> and nano CuO. Cell types used in this work are human lung epithelial cells-A549; mouse monocyte/macrophage cells-J774; human monocyte/macrophage cells -THP-1; human neuroblast cells -SH-SY5Y, gut epithelial cells – Caco-2. LC-Mass spectrometry and affinity-based high-content proteomic approaches are employed in these projects to obtain molecular-level information and gain insight into potential toxicity mechanisms. In addition, cellular oxidative stress status is measured. Also, Raman spectrometry is used to study cellular uptake of NPs. Furthermore, tests are conducted to identify physicochemical determinants of toxicity. This work will generate in-depth mechanistic information relevant to key events to support adverse outcome pathway (AOP) model refinement/validation.

Exposure of Zebrafish embryos to inorganic oxide-based nanomaterials -Alternative toxicity testing platform

- The EHSRB Mechanistic Studies Division conducted work on zebrafish embryos exposed to different doses of well-characterized nanomaterials as well as to relevant reference particles. Sampling for different endpoint analyses are done at 24-96 hours post fertilization (hpf) following NP exposure. Phenotypic changes including survival rate, abnormalities in hatching rate, gross morphology and movement are monitored. In addition, oxidative stress analysis and molecular-level changes are followed using LC-mass-spectrometry based proteomics for mechanistic information. NP exposure-related mechanistic changes from the zebrafish embryo studies will be compared with corresponding *in vitro* toxicity data to assess consistency.
- Journal publications:
  - Nazemof N, Breznan D, Dirieh Y, Blais E, Johnston LJ, Tayabali AF, Gomes J, Kumarathasan P. Cytotoxic Potencies of Zinc Oxide Nanoforms in A549 and J774 Cells. *Nanomaterials* (Basel). 2024 Oct 3;14(19):1601.
  - Prem Kumarathasan, Nazila Nazemof, Erica Blais, Krishna Priya Syama, Dalibor Breznan, Yasmine Dirieh, Hiroyuki Aoki, Sadhna Phanse, Azam Tayabali, Mohan Babu. *In Vitro*

Exposures of A549, J774A.1 Cells to SiO<sub>2</sub>, TiO<sub>2</sub> Nanoforms and Related Cellular and Molecular Level Effects: Application of Proteomics. *Journal of Proteomics Research*. 2025 Mar 4. doi: 10.1021/acs.jproteome.4c00651.

Health Canada's Food and Nutrition Directorate's Bureau of Chemical Safety develop analytical methods related to micro and nanoparticles as well as conducts toxicology research related to nanomaterials.

- Micro-nanoplastics (MNPs) in foods are an increasing consideration for food safety. Common plastic packaging materials, such as polystyrene (PS), polypropylene (PP), and polyethylene (PE), may contribute to human exposure to MNPs through contaminated food. MNPs have been detected in various foods, including seafood, fruits, vegetables, juices, milk, tea, honey, beer, and salts. The Food Research Division is focused on developing and validating methods for characterizing and detecting MNPs in food matrices, food packaging materials, and biological samples. These methods will support monitoring and surveillance activities, inform dietary intake estimates, and assess potential risks.
- The Regulatory Toxicology Research Division is conducting toxicology research to answer mechanistic questions related to food-grade and nano-titanium dioxide (TiO<sub>2</sub>). The research is determining whether the probe sonication methods that are often used to generate liquid suspensions of TiO<sub>2</sub> before administration in the toxicology studies may inadvertently generate Reactive Oxygen Species (ROS) radicals that do not reflect real-world exposure scenarios. ROS detection methods and intestinal epithelial cell lines are being used to study inflammation markers. The study is also optimizing nanoparticle suspension methods that minimize ROS generation during the liquid during suspension used for toxicology research studies. The data will be published in peer-reviewed journals.

## 7.4 Croatia

Croatian experts from IMROH are involved in the following currently running projects, which establish regulatory-relevant testing strategies for nanomaterials:

The PARC (EU-Partnership for the Assessment of Risk from Chemicals) project (started in May 2022) is focused on risk assessment of chemicals, but it also includes nanosafety experts. The Croatia is involved in PARC, with a strong emphasis on human exposure assessment and development of NAMs for nanomaterial safety testing. Croatian partners are also involved in WP7 on FAIR data.

The H2020 project "PHOENIX – Pharmaceutical Open Innovation Test Bed for Enabling Nanopharmaceutical Innovation Products (started in March 2021) provides advanced, affordable and consolidated network of facilities, technologies, services and expertise for all the technology transfer aspects of nanomaterials for medicine, covering characterisation, testing, verification up to scale up, GMP compliant manufacturing and regulatory guidance. The consortium includes IMROH (Prof. Ivana Vinković Vrček) as Croatian partners responsible for leading of Work Package 5 on regulatory support. Within the service portfolio of the test bed, IMROH offers advanced models, methodologies and assays for preclinical in vitro and in vivo testing.

The HORIZON EUROPE project "NABIHEAL – ANTIMICROBIAL NANOSTRUCTURED BIOMATERIALS FOR COMPLEX WOUND HEALING" (started in January 2023) is developing multifunctional biomaterials to improve wound management. IMROH (Prof. Ivana Vinković Vrček) leads Work Package 5 on Safety testing.

IMORH participates as consortium member in the research project ECHA/2022/502 - Lot 2 "Framework Contract for the development of NAM based tools and data for hazard identification and characterisation of industrial chemicals, including polymers and nanoforms.", led by QSAR Lab from Poland. This project

contributes and supports the development of NAMs for efficacy and safety assessment of nanomaterials and advanced materials, thus, supporting IATA.

Croatian scientists from IMROH, as consortium member of RiskGone project, were actively involved in close collaboration of the three H2020-projects Gov4Nano, NANORIGO and RiskGONE on risk governance and risk assessment of nanomaterials. Insights about risk governance challenges and issues are reported in a memorandum on risk governance of advanced materials that suggests four lines of policy actions to fill gaps regarding knowledge, connection with innovation policies and regarding harmonization and standardization.

## 7.5 European Union

General information on the research and innovation policy of the EU for chemicals and advanced materials, with key policy documents as well as link to [open calls and future funding opportunities](#) can be found [here](#).

## 7.6 Germany

### 7.6.1 Federal Institute for Risk Assessment (BfR)

#### 7.6.1.1 EFSA NAMs4NANO (2023-2027)

The EFSA-funded NAMS4NANO project, organised in three lots, aims to understand the opportunities, challenges and uncertainties of the use of NAMs for the risk assessment of nanomaterials in the food and feed sectors.

NAMS4NANO Lot 1, coordinated by the BfR, was focused on complementing the EFSA NAMs roadmap and the outcome was published in two documents.

The first document is a review that describes regulatory relevant NAMs that are promising to be further explored in risk assessments of NMs in the food and feed sectors (Usmani et al. 2024, DOI: <https://doi.org/10.2903/sp.efsa.2024.EN-8826>). The review puts particular emphasis on NAMs to assess NM degradation/dissolution, genotoxicity, cytotoxicity, oxidative stress, inflammation, and barrier integrity, in line with the recommendations of the EFSA Guidance on risk assessment of nanomaterials in the food and feed sectors.

In the second document, a qualification system for NAMs for NMs in the food and feed sectors was proposed that should speed up the regulatory implementation, as most of the NAMs for NMs are not yet validated (Haase et al. 2024, DOI: <https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/sp.efsa.2024.EN-9008>). In this context, a Nanopinion has been published in EUON (European Observatory for Nanomaterials), (Haase et al. 2025, DOI: <https://euon.echa.europa.eu/de/nanopinion/-/blogs/a-qualification-system-to-accelerate-development-and-regulatory-implementation-of-new-approach-methodologies-nams->).

NAMS4sNANO Lot 2, which is coordinated by the BfR, involves five risk assessment case studies to test selected NAMs to fill data gaps in existing assessments. This includes ZnO, SiO<sub>2</sub> (SAS), iron oxides, nanosilver and copper oxides. Relevant NAMs (based on the published review from Lot 1) will be tested, some of which will also be evaluated for their regulatory maturity using the proposed qualification system.

NAMS4NANO Lot 3, which is coordinated by the ISS (Italian National Institute of Health) involves five methodological case studies to further advance selected NAM-based tools and procedures. Case study 1 (CS 1) investigates a nanocarrier loaded with a pesticide active substance and aims at developing an IATA and contributions for a guidance. CS 2 deals with nanofibers. CS 3 aims to develop a relevant methodology

to mimic “aging” of NMs in the gastrointestinal tract to obtain more relevant test materials for in vitro assessments. CS 4 uses disease models for the intestinal barrier that should represent vulnerable populations. CS 5 uses whole organism in vitro models in the context of human health risk assessments.

#### 7.6.1.2 EU POLYRISK (04/2021-09/2025)

The BfR is coordinating work package 4 in the POLYRISK project, which deals with understanding human exposure and health hazard of micro- and nanoplastic contaminants in the environment. Within POLYRISK, a risk assessment framework has been proposed for micro- and nano-plastics (MNPs) to assess their human health risks following the inhalation exposure route. The framework implements relevant concepts, such as AOPs (Adverse Outcome Pathways), IATAs as well as the most recent scientific knowledge from the literature. The POLYRISK risk assessment framework has been published in 2024 (Vogel et al. 2024, DOI: <https://doi.org/10.1186/s12989-024-00602-9>). In addition, the applicability of the developed risk assessment framework is currently being evaluated in case studies.

#### 7.6.2 Federal Institute for Occupational Safety and Health (BAuA)

BAuA initialised various research projects to determine the critical rigidity of potentially hazardous fibres based on their phagocytability in macrophages. This involves for the project CETRA analysing changes in cell mobility and morphology. By tracking cells in microscopic time-lapse recordings, dynamic patterns can be detected and correlated with material properties such as fibre length and rigidity. The project IMPACT (in cooperation with BfR) is focusing on the pulmonary toxicological response mechanisms to fibres by measuring proteomics.

BAuA furthermore submitted a proposal for a potential research topic to the European Partnership on Metrology on “Metrology enabling the regulation of carcinogenic respirable fibres based on their flexural rigidity”. We propose to develop reliable methods for preparing sub-microscale fibres for bending tests and for measuring their flexural rigidity. This will enable material developers to design non-rigid, intrinsically safer fibres, and toxicologists to protect the health of workers by identifying potentially carcinogenic fibres via physical measurement and read-across with materials of similar rigidity and already tested toxicity.

### 7.7 Italy

NAMs4NANO (‘Integration of New Approach Methodologies results in chemical risk assessments: Case studies addressing nanoscale considerations’) is a multiannual EFSA-funded project including several lots, i.e. individual projects. The overall aim of this ongoing action is to promote the use of NAMs for nanospecific risk assessment, covering both nanomaterials and conventional materials (i.e. not engineered at the nanoscale) containing a fraction of small particles. ISS is involved in the three ongoing lots and coordinates the Lot 3.

NAMs4NANO Lot 1 (led by BfR) carried out a review of available NAM-based tools and methods for assessing the toxicity of nanoparticles (Usmani et al., 2024, see ‘Developments related to good practice documents’). In addition, a draft proposal for a fit for purpose qualification system for NAMs aimed at facilitating the regulatory use of NAM tools and methods in chemical risk assessment in the food and feed sector was developed after open discussions with international experts and submitted to public consultation (Haase et al., 2024). It is now being implemented in the experimental case studies of Lot 2 and 3, and lessons learned will be considered in updating and revising it. Within the specific context-of-use (i.e. regulatory risk assessment in the food and feed sector), qualification is a conclusion that the results of an assessment using the model or assay can be relied on to have a specific interpretation and application. A detailed test method description, preferably as standard operating procedures (SOPs), describing the set-up of the NAM including its application and evaluation phase is crucial. Furthermore,

the scientific validity, i.e. its reliability and relevance for the context-of-use, needs to be demonstrated. Qualification is based on an expert opinion of a panel of experts on the adequacy of a method for a well-defined use in a specific context, whereby the NAM can be applied for the “qualified use” without the need to re-evaluate the method case-by-case in each application. The qualification system itself can be regarded as a practical tool, which allows regulators to a) evaluate NAMs regarding their adequacy for a specific context-of-use, b) support the optimisation of submitted NAMs and c) ultimately facilitate their regulatory implementation for risk assessments of nanomaterials in the food and feed sector.

NAMs4NANO Lot 2 (led by BfR) focuses on five case studies using NAMs for addressing the nanoscale considerations and integrating this information with existing information and knowledge for conducting a risk assessment for consumers. The case studies focus on ZnO as a nutrient source, SiO<sub>2</sub> (synthetic amorphous silica) as food additive, iron oxides as food additives, nanosilver as food contact material and as food additive, copper oxides as feed additives and pesticides. ISS leads the ZnO case study. Lot 3 is led by ISS and features five methodological and cross-cutting case studies. They focus on (i) nanocarriers loaded with pesticide active substances (ii) nanofibres, with focus on nanocellulose (iii) ‘aging’, i.e. simulating transformations in the GI tract to obtain relevant materials for in vitro testing (iv) diseased models for the intestinal barrier to generate information on potential risks in vulnerable populations (v) whole organism in vitro models as the bridge between in vitro models and in vivo models in nanoparticle toxicity assessment. ISS leads case studies 2 and 3. Preliminary results are being obtained whereas final results are expected for Q4 in 2026.

BioPlast4SAFE is a four-year project approved by the Italian Ministry of Health, as part of the National Plan for Complementary Investments (PNC) for Health, Environment, Biodiversity and Climate "Biomonitoring of biodegradable micro and nanoplastics: from the environment to man in a One Health perspective (AREA B 14). Applied research for the assessment of the impact of environmental risks on health". The project, in which ISS and ISPRA are involved, is focused on (i) the evaluation of the environmental risks and (ii) the evaluation of the health risk derived from the human exposure through the environment, in accordance with the European Regulations: Reg. (CE) n. 1907/2006 (REACH) and Reg. (CE) n. 1272/2008 (CLP), in particular related to the emerging risks associated with the micro- and nano-forms of plastics.

In this framework, ISS is involved in the evaluation of micro and nanoplastic exposure and the development and standardization of reliable in vitro and in vivo approach and new approach methodologies suitable for the assessment of human health risk resulting from exposure to micro and nanoplastics present in food chain and water in a "One Health" perspective. In particular, since ingestion represents the main route of human exposure to micro and nanoplastics, Caco-2 cells, a human colon carcinoma cell line, have been selected for cytotoxicity and genotoxicity in vitro studies and an advanced intestinal barrier has been applied as model to study intestinal uptake and translocation of micro and nanoplastics of different size and nature, representative of commonly used plastics. For in vivo studies, the nematode *Caenorhabditis elegans* has been chosen to evaluate potential toxic effects of micro and nanoplastics in line with the 3R principles.

## 7.8 Japan

The National Institute of Advanced Industrial Science and Technology (AIST) and the University of Fukui have completed a five-year project "Cellulose Nanofiber (CNF) Related Technology Development to Contribute to a Carbon Cycle Society/ Development of CNF use technology/ Development of Hazard Assessment Methods and Safety Assessment for Various Product Applications" (Japan Fiscal Year (JFY) 2020-2024). This project was commissioned by the New Energy and Industrial Technology Development Organization (NEDO) and led by METI. The project focused on several research area including the evaluation of inhalation and oral toxicity through in vivo studies, the development and evaluation of inhalation toxicity using in vitro cell-based assay, the investigation of mesothelioma induction potential,

ecotoxicity assessment, and emission/exposure assessments. Based on the findings from this research and literature review, a revised safety assessment document (written in Japanese) was published in January 2025 to support voluntary safety assessment in CNF-related companies.

The Ministry of Health, Labour and Welfare (MHLW) has promoted research on the human health aspect of several nanomaterials since 2003 through the Health and Labour Sciences Research Grants. In JFY 2025, two basic research projects on development of methods for evaluating hazard and adverse effect of nanomaterials on human health are progressing.

The Food Safety Commission of Japan has been promoting research on the uptake of nanoparticles into living bodies (JFY 2024-) and has completed research on risk assessment methods of nanoparticles in foods (JFY 2022-2024) in the food safety sector.

The Consumer Affairs Agency (JFY 2024-) has been promoting research on risk management of nanomaterials in food materials following research projects by the Ministry of Health, Labour and Welfare (JFY 2011-2023).

The Ministry of the Environment (MOE) has been focusing its efforts on environmental risk of manufactured nanomaterials via understanding of their environmental fate and ecotoxicity. In JFY 2024 MOE continued collecting and reviewing existing literature on ecotoxicity of manufactured nanomaterials including TiO<sub>2</sub>, silver and CNTs and its expert committee summarized the knowledge on effects of manufactured nanomaterials to aquatic organisms. The interim report was publicized in Q2 2025.

## 7.9 Korea

### 7.9.1 OECD Project on Safety testing of nanoplastics

At the 6<sup>th</sup> meeting of the Chemical and Biotechnology Committee (CBC) in November 2024, the CBC decided that to include Korea's project proposal on the toxicity and stability of fragmented nano-plastics in its work programme, starting with a workshop in 2025. In March 2025, the OECD Steering Group to support the project and the workshop was established. Researchers from National Institute of Environmental Research (NIER) lead the project, with active participation from relevant Korean research institutes (Gwangju Institute of Science and Technology, Korea Research Institute of Standards and Science, Korea Research Institute of Bioscience & Biotechnology, Korea Institute of Radiological & Medical Science, Inha University). In November 2025, the *OECD workshop on the safety testing of nanoplastics: focusing on developing reference materials/test materials* will be held in Paris.

## 7.10 The Netherlands

Testing strategies form the basis for the risk assessment of chemicals and materials. The European project [CHIASMA](#) focuses on the development, refinement, application and innovation of these strategies. The selected methodologies are a combination of computational and experimental approaches relevant for human exposures. These methodologies should eventually be integrated into a safe and sustainability by design (SSbD) framework to support REACH and CLP. The project is working on conceptualising a strategy to support the integration of the available methods. In addition, the various experimental partners started with standardisation and optimisation of their *in vitro* methodologies to allow inter-laboratory transferability studies to allow assessment of their robustness. The next step will be the performance of case-studies centred around PFAS, (nano)pesticides and 2D materials. RIVM is involved in all facets of the project.

## 7.11 Portugal

The **National Institute** of Health (INSA, Lisbon, Portugal) participated in recent nationally and internationally funded projects:

- Recent National projects:
  - 
  - Toxicological profile of cellulose nanomaterials in human gastrointestinal cells,
  - INGESTnano - Cellular and Molecular Mechanisms of Toxicity of Ingested Nanomaterials,
  - ToxApp4NanoCELF1 - A predictive toxicology approach to characterize potential respiratory effects of functionalized nanocellulose fibers in a co-culture system
  -
- NANOCELIA - Red de Transferencia Tecnológica sobre Aplicaciones de Nanocelulosa en Iberoamérica
- Former EU projects: NANOGENOTOX JOINT ACTION: Safety evaluation of manufactured nanomaterials by characterisation of their potential genotoxic hazard and NANoREG – A common European approach to the regulatory testing of Manufactured Nanomaterials

The **University of Aveiro** is enrolled in several projects, being Chemical Group Co-Leader for Nanomaterials in the European Partnership for the Assessment of Risks from Chemicals (PARC) and participating in additional projects, namely:

- ETERNAL – Boosting the reduction of the environmental impact of pharmaceutical products throughout their entire life cycle (Horizon Europe; pharma project with nanoencapsulation - partly)
- SAFERCOAT (Horizon Europe - Marie Skłodowska-Curie Actions Staff Exchanges (MSCA-SE) ;
- Former EU projects NANOFATE, NANOFASE, NANOFARM, NanoHarmony (this last directly related to OECD), SMARTAQUA.
- Former project with Brazil (FCT/CAPEs) on "Toxicological responses of molluscs after exposure to nanomaterials: assessment of the environmental impact associated with nanotechnology".

The **International Iberian Nanotechnology Laboratory (INL, Braga, Portugal)**, was founded by the governments of Portugal and Spain under an international legal framework to perform interdisciplinary research and deploy and articulate nanotechnology for the benefit of society. Within INL, the nanosafety group has the support of the ERA-Chair grant entitled SiNfONiA – Safety in Nanomaterials & Nanotechnology (2020-2024). The overall aim of SiNfONiA (<https://inl.int/projects/sinfonia/>) is to boost RTD activities in the nanosafety arena and strengthen the research and innovation potential of INL. The research lines include Organ-on-a-chip technology to evaluate the safety of nanomaterials used on products that could get in contact with the skin or the respiratory tract; Epigenetics and *in vitro/in vivo* bridging models to evaluate the safety of different nanomaterials and pollutants; Toxicology and immunotoxicology of nanomaterials using sensors and high-throughput technologies; *in silico* evaluations using QSAR, QSPR, QSTR, machine learning and life cycle assessment. Currently, the Nanosafety group at INL coordinates two European Projects: Development of Novel Assessments for Indoor Air Quality Monitoring and Impact on Children's Health (LEARN; <https://www.learnproject-heu.eu/>) and integrated assessment and Advanced Characterisation of Neuro-Nanotoxicity (iCare; <https://icareproject.eu/>).

## 7.12 Sweden

### 7.12.1 GrapheneEU

The coordinator for the Graphene Flagship project, supported by the European Commission and ended in 2023, continues to coordinate the Coordination and Support Action (CSA)-project [GrapheneEU](#). (Further

information can be found here: [Chalmers steers Europe's major graphene venture to success](#)). A publication relating to the project, and led by a Swedish researcher, was published in 2025: Fadeel B et al. Safety Assessment of Graphene-Based Materials. Small. 2025 Feb;21(7): e2404570. <http://doi.org/10.1002/sml.202404570>. Epub 2025 Jan 15.

### 7.12.2 MISTRA

The Swedish Foundation for Strategic Environmental Research (MISTRA) supported the [Mistra Environmental Nanosafety – Mistra](#) consortium from 2014–2023. The project has successfully published papers relating to e.g., Ti<sub>3</sub>C<sub>2</sub> MXenes (one of the most commonly applied and well-studied MXenes) and the Safe and Sustainable by Design (SSbD) framework:

- Hansen SF, Nielsen MB, Skjolding LM, Kaur J, Desivyana N, Hermansson F, Bird J, Barg S, Khort A, Odnevall I, Fadeel B, Arvidsson R. Maximizing the safety and sustainability of MXenes. Sci Rep. 2024 Dec 28;14(1):31030. <http://doi.org/10.1038/s41598-024-82063-w>
- Ståbile et al. Fate and biological uptake of polystyrene nanoparticles in freshwater wetland ecosystems. Env Sci: Nano 2024 <https://doi.org/10.1039/D3EN00628J>
- Lovén et al. Size-resolved characterization of particles >10 nm emitted to air during metal recycling. Environ Int. 2023 <https://doi.org/10.1016/j.envint.2023.107874>
- Odnevall et al. Characterization and Toxic Potency of Airborne Particles Formed upon Waste from Electrical and Electronic Equipment Waste Recycling: A Case Study. ACS Environ Au. 2023 Nov 3;3(6):370-382. <https://doi.org/10.1021/acsenvironau.3c00034>

### 7.12.3 SIO Grafen

Under the [SIO Grafen](#) umbrella and with external funding from FORTE (Swedish Research Council for Health, Working Life and Welfare) the group from Sahlgrenska Institute, Gothenburg University will investigate occupational exposure to graphene related 2D materials and health effects, especially from the airways among occupationally exposed workers.

## 7.13 United Kingdom

### 7.13.1 PARC

The €400 Million PARC project, which started on 1<sup>st</sup> May 2022 and will run for 7 years, while focusing on chemicals more broadly, has a significant cohort of nanosafety experts and will include at least 1 cross-cutting case study / project on nanomaterials safety. The UK have strong involvement in PARC including Co-Leading WP7 on FAIR data management and as a WP Co-Lead and Defra co-leads the steering group and national hub in partnership with UK HSA. The UK are involved in WPs 2-7, with a strong emphasis on environmental aspects / ecotoxicity and New and Alternative Methods (NAMs).

### 7.13.2 CHIASMA

The CHIASMA Project will devise and demonstrate a comprehensive set of New Approach Methodologies (NAMs) and integrate them in a user friendly, reliable and robust framework to perform human and environmental safety evaluation in a regulatory context, with several UK partners involved, where advanced materials characterization will take place. The work from previous projects such as PATROLS is continuing through this work, where the tools developed in PATROLS are being explored more widely. The in vitro tests from the previous project are going through interlaboratory trials to provide validation data

that not only demonstrates their reproducibility, but also their applicability domain looking at NMs, but also AMs and forever chemicals.

# 8 Developments and/ or research related to Safe(r) and Sustainable Innovation Approaches, Safe-by-Design and/or other anticipatory strategies relevant for (advanced) (nano) materials

## 8.1 Austria

**PARC** (EU-Partnership for the Assessment of Risk from Chemicals) is an EU Horizon Europe partnership to support research and innovation in EU and national chemical risk assessment and risk management bodies with new data, knowledge, methods, networks and skills to address current, emerging and novel chemical and nanosafety challenges. It will facilitate the transition to next generation risk assessment to better protect human health and the environment, in line with the Green Deal's zero-pollution ambition for a toxic-free environment and will be an enabler for the EU Chemicals Strategy for Sustainability. The Austrian Environment Agency is co-leading work package 2 ("A common science policy agenda"). BNN is involved in Task 8.1 ("Safe-and-Sustainable-by-Design (SSbD)"), where a SSbD toolbox is developed and a SSbD case study on BPA was performed with the aim to test the applicability of the JRC SSbD framework. PARC is funded by the European Commission together with member states.

The BOKU University, Institute for Waste Management and Circularity (contact: Florian Part) is partner of the Horizon Europe project "Depolymerizable bio-based multifunctional closed loop recyclable epoxy systems for energy efficient structures" ([www.repoxyble.eu](http://www.repoxyble.eu); coordinated by AVANZARE (Spain); duration from 12/22-05/26). The project, a consortium of 10 project partners, aims to develop a new class of high-performance materials – bio-based epoxy composites – targeting cost and energy effectiveness, recyclability and sustainability. REPOXYBLE assumes an upstream approach more efficient and effective than having to address deficiencies at the end of the product development process. This approach integrates product performance, multifunctionality, sustainability, safety and potential legal concerns, while there is still time to act on the monomers' synthesis, the resin formulation and the future composite design. REPOXYBLE is driven by two complementary market applications in the aerospace and automotive sectors. The project includes toxicity tests on the novel nanoformulations (monomers, hardeners, etc.), material tests on the epoxy-based products including life cycle assessment (LCA) and the evaluation of the chemical recyclability (by solvolysis) at a laboratory scale (by the BOKU). An LCA-based decision supporting tool will be developed based on SSbD principles.

Within the SAF€RA project “Safe- and sustainability-by-design approaches for energy storage systems in a green and circular economy (SuESS)”, advanced materials that are used for redox flow batteries are investigated (duration from September 2023 until August 2025). It involves the University of Graz (coordinated by Claudia Mair-Bauernfeind), the BioNanoNet Forschungsges.mbH, the Ecolyte GmbH, Biobide, and the BOKU University. Stationary energy storage systems (ESS) play an essential role in the energy transition, which is why the safety and sustainability of these ESS is increasingly coming to the fore. In recent years, lithium-ion batteries, flow battery systems and combinations of these have been installed. Although there has been some progress in the development of safe and sustainable ESS, the environmental and social impacts are still an under-researched topic. The aim of the SuESS research project is to apply the SSbD principle to selected stationary energy storage systems (ESS), covering the whole life cycle using life cycle assessment (LCA). The focus will be on flow batteries (e.g. vanadium or vanilla-based) and lithium-ion batteries, including possible substitutes (e.g. sodium-ion batteries) with a storage capacity of >80 kWh. An LCA and a social LCA will be carried out to identify environmental and social hotspots. Finally, guidelines for the assessment of risks, sustainability and cycle capability will be derived based on the project results. This will provide a basis for decision-making on green deal investments of ESS.

The FFG has funded the project “Development of a functional recycling process for lithium-ion traction batteries from mobile applications (MoLIBity)” (duration from April 2023 to March 2026). It involves the Fraunhofer Austria Research GmbH (coordinated by Andreas Lehner), Saubermacher AG, the Treibacher Industrie AG, the Fraunhofer Institute for Ceramic Technologies and Systems IKTS, the Montanuniversität Leoben, and the BOKU University. The objective of the research project, the targeted recovery of important secondary raw materials in the sense of a circular economy, is in line with ecological, economic, and social sustainability and at the same time with the Sustainable Development Goals (SDGs) 9 and 12. It will also increase the innovation performance in the field of circular economy, which will expand the technology leadership and strengthen international competitiveness. Advanced battery materials and critical raw materials, such as lithium, cobalt, or graphite, are recovered through an innovative pyro- and hydrometallurgical recycling route. A Life Cycle Assessment (LCA) of the battery materials and the recycling technology will be carried out in line with the SSbD principle.

The FFG project “Hybrid Electrochromic Materials for Sustainable and High-Performance IoT-Displays” will run from February 2024 until January 2027. The University of Vienna (contact Davide Bonifazi) in cooperation with Suzhou Institute of Nano-Tech and Nano-Bionics (SINANO) and prelonic technologies will develop reflective electrochromic displays which offers a sustainable and low-power internet of things (IoT) applications. Advanced materials, such as multicolour polymers combined with quantum dots, and additive manufacturing methods will be developed to produce flexible substrates, which can be used, e.g., for IoT shelf label. In line with the SSbD principle, Koloo Projects perform social impact assessments and BOKU University life cycle assessments.

The FFG-CAS bilaterally funded SmartCERIALS project (PLUS, contact person: Martin Himly) aims to develop raw materials for the generation of antimicrobial surfaces with smart multi-functional properties to additionally allow the monitoring of microbial contamination and coating stability through additional SERS-sensitive and fluorescently active nanomaterials. More details can be found at [www.plus.ac.at/smartcerials](http://www.plus.ac.at/smartcerials).

Within the H2020 project NextGenMicrofluidics (“Next generation test bed for upscaling of microfluidic devices based on nano-enabled surfaces and membranes” (start: April 2020)), coordinated by JOANNEUM RESEARCH Forschungsgesellschaft mbH and by the project established Open Innovation Test Bed “Microfluidic Innovation Hub”, BNN (contact: Andreas Falk) is responsible for the evaluation of potential hazards and safety issues in all Demo Cases as well as raising awareness on potential regulatory issues. By implementing its safety strategy, the overall aim of BNN’s nanosafety team is to ensure that all aspects of the involved processes will be conform to the Safe-by-Design concept for the technological development.

The H2020 NMBP-16-project **HARMLESS** (“Advanced high aspect ratio and multicomponent materials: towards comprehensive intelligent testing and Safe-by-Design strategies” (start: January 2021)), is supported by BNN (contact: Susanne Resch) with contributing to the Safe Innovation Approach and S(S)bD implementation specifically for multicomponent and High Aspect Ratio Nanomaterials.

Next to that, BNN (contact: Susanne Resch) is involved in its sister H2020 NMBP-16-project **DIAGONAL** (“Development and scaled Implementation of Safe by design tools and Guidelines for multicomponent and harm nanomaterials” (start: May 2021)) with the role to mainstream sustainability into Safe-by-Design, liaison management, stakeholder engagement, communication & dissemination.

The H2020 project **PHOENIX** (“Pharmaceutical Open Innovation Test Bed for Enabling Nano-pharmaceutical Innovation Products” (start: March 2021)) aims to enable the seamless, timely and cost-friendly transfer of nano-pharmaceuticals from lab bench to clinical trials by providing the necessary advanced, affordable and consolidated network of facilities, technologies, services and expertise for all the technology transfer aspects, covering characterisation, testing, verification up to scale up, GMP compliant manufacturing and regulatory guidance. The consortium includes RECENDT, RCPE and BNN (contact: Johanna Scheper) as Austrian partners. BNN’s role was to develop the business concept and overall sustainability of the project and the future OITB, and leads the communication, dissemination and exploitation activities of the project. The project has already established the single entry point of the OITB, the Phoenix gGmbH. Within the service portfolio of the test bed, BNN offers innovation and guidance on and implementation of the SSbD approach.

The HORIZON EUROPE project **IRISS** (“Accelerating the transition to Safe-and-Sustainable-by-Design”(start: June 2022)) aims to connect, synergize and transform the Safe-and-Sustainable-by-Design community in Europe and globally towards a lifecycle approach, with a holistic integration of safety, climate neutrality, circularity and functionality already in an early stage of designing and manufacturing materials, products and processes. In close collaboration with industry, a number of roadmaps will be developed to implement research and innovation, but also to demonstrate needs that exist in the policy area. Focus is on the value chains for textiles, construction, electronics, energy, automotive and packaging. BNN (contact: Johanna Scheper) supports in the mapping of SSbD methods and criteria, liaison and stakeholder engagement, communication, dissemination and consultation and takes a key role in the definition and testing of services to key targets.

The HORIZON EUROPE project **NABIHEAL** (“ANTIMICROBIAL NANOSTRUCTURED BIOMATERIALS FOR COMPLEX WOUND HEALING”(start: January 2023)) will develop multifunctional biomaterials to improve wound management, by using quatsomes nanovesicles (QS) with demonstrated inherent antimicrobial properties as alternative to silver. BNN (contact: Johanna Scheper) supports and guides the research and innovation partners in addressing the SSbD principles and will develop a project- and application-tailored SSbD concept as well as specific implementation guidelines.

The HORIZON EUROPE project **SSbD4Chem** (“SSbD framework for the next generation of Chemicals and Materials“ (start: January 2024)) aims to develop and promote best practices for safe and sustainable product and process design, facilitating the development of new chemicals/materials applicable to (i) renewable composites in the automotive value chain, (ii) PFAS-free coatings for textiles, and (iii) cellulose nanofibers as additive in cosmetics to replace plastic microbeads. BNN (contact: Andreas Falk) leads the stakeholder engagement, training and dissemination activities and supports to keep pace with other relevant activities in the context of general SSbD developments on global level.

The HORIZON EUROPE project **PLANETS** (“Plasticizers, flame-retardants and surfactants: new alternatives validating the safe and sustainable by design approach” (start: November 2024)) will support developing safer and more sustainable alternatives for plasticisers, flame retardants, and surfactants and bringing them to TRL 6 through SSbD assessments. Furthermore, the alternatives will be incorporated into consumer goods achieving TRL 7. The new molecules and products will be significantly safer for workers and consumers and have considerably lower environmental impact. Importantly, they will also be

economically viable and take social dimensions into account. BNN (contact: Andreas Falk) leads the dissemination and stakeholder engagement activities and supports the SSbD implementation during the innovation process.

Since 2017, the BioNanoNet Forschungsgesellschaft mbH (short: BNN) (contact: Andreas Falk) is part of the EU NanoSafetyCluster coordination team. Recently, the cluster has transformed to the “**Network for Safety and sustainability of Chemicals and materials (NSC)**” (see [NSC-Community](#)). Within this community, the internationalisation efforts are co-coordinated by BNN as the “international network initiative on safe and sustainable nanotechnologies” (**INISS-nano**), a global collaboration initiative towards the further shaping of the S(S)IA and SSbD-developments. The INISS-nano concept paper had been elaborated by international experts on Nanosafety under the lead of BNN and the Austrian Federal Ministry of Innovation, Mobility and Infrastructure, Republic of Austria, (BMIMI; formerly known as BMK). The actual and updated version is public available:

- Falk Andreas, Pogany, Alexander, Aungkavattana, Pavadee, Bañares, Miguel A., Beitollahi, Ali, Bim, Vinicius, Briffa, Sophie, Bochon, Anthony, Cassee, Flemming, Doridot, Fernand, Exner, Thomas, Farias, Patricia M.A., Favre, Georges, Franzese, Giancarlo, Friedrichs, Steffi, Hristozov, Danail, Hunt, Neil, Indaraprasirt, Ramjitti, Karim, Md. E., ... Wilkens, Terence A. (2022). INISS-Nano: revised concept and action plan (International Network Initiative on Safe and Sustainable Nanotechnologies) (Version\_03). Zenodo. <https://doi.org/10.5281/zenodo.7877359>

This international collaboration is structured along the 4 pillars: (i) Harmonisation, (ii) Support industrial understanding, (iii) Sharing / facilitate sharing of resources / infrastructures, and (iv) International collaboration on ethical and societal aspects of nanotechnology.

On 18 December 2024, the 9<sup>th</sup> INISS-nano web meeting with more than 30 participants from around the globe included excellent presentations:

- Pushplata Singh (TERI, India) presented “Commercialization of nanofertilisers in India, exporting to other countries, and challenges.”
- Eeva Leinala & Mar Gonzalez (OECD) showed “The OECD concept and experiences of the Mutual acceptance of data (MAD)-system.”

Furthermore, the INISS-nano pillar chairs and contributing colleagues showed the progress on the activities (e.g., application for an UNESCO UNITWIN, COST-action, etc.), and a recap about the 7<sup>th</sup> EU-Asia Dialogue (held in Thailand, October 2024). The next activities of INISS-nano will include the further development of the initiative, focussing inter alia on the “Ethical challenges & role of societal stakeholders for building a pan-European training partnership for (research and) innovation on safe and sustainable nano- and advanced materials”.

## 8.2 BIAC

The **NIA** has published an Opinion on the Advanced Materials strategy from the European Commission and has contributed to commenting rounds on the revision of the Cosmetic Product Regulation and EFSA advocating for the implementation of NAMs and a unified nanomaterial definition.

The **NIA** is also involved in stakeholder groups such as the NanoSafety Cluster and the INISS-Nano network, which bring together actors in the nano ecosystem to discuss relevant topics and to promote collaboration and information exchange. The **NIA** has participated in relevant conferences such as ANTHOS 2024, Industrial Technologies 2024, the Birmingham Advanced Materials show 2024 or the Nanodialogue 2024 presenting advances and gaps from the nanotechnology sector regarding EHS issues. The **NIA** has also performed a review on the “Use of Metal and Non-metal Nanomaterials in Consumer Products and Associated Safety Issues” for the Office of Product Safety and Standards (OPSS) in the UK.

## 8.3 European Union

A number of EU projects and support actions address development and implementation of Safe and Sustainable by Design (SSbD) concept are ongoing and had been identified in the previous TdT. In the EU, the SSbD approach is pursued generally for all chemicals in research and innovation, while being kept outside regulatory provisions. The notable development in 2025 is the revision of the SSbD Framework that the Commission rolled out in its pilot phase with dedicate Commission Recommendation in 2022. After capturing experiences from the extensive feedback and exchange with the practitioners in two workshops, the Commission has now launched a survey, open until 15 September 2025, to share the view on the changes considered in the framework. Adoption of new Recommendation with a revised framework, taking into account the comments received, are planned still in 2025. More information and link to the survey are available [here](#).

## 8.4 Germany

### 8.4.1 German Environment Agency (UBA)

As part of UBA's engagement in the European Partnership for the Assessment of Risk from Chemicals (PARC), together with the PARC partner RIVM (Rijksinstituut voor Volksgezondheid en Milieu, the Netherlands) a public user community group in SSbD was initiated. This group offers a space for open academic discussion and exchange of experiences based on dedicated discussion fora related to SSbD relevant topics. It is part of PARC's knowledge management and community platform for chemical risk assessment professionals called PARCopedia.

To engage in the public discussion, please register at PARCopedia and join the SSbD group: <https://www.parcopedia.eu/groups/ssbd-user-community/>

### 8.4.2 Federal Institute for Risk Assessment (BfR)

#### 8.4.2.1 EU HARMLESS (01/2021 - 04/2025)

Within the HARMLESS project, an early warning system (EWS) for advanced materials has been developed, including the Advanced Material Earliest Assessment (AMEA) tool and elements of Early4AdMa. The HARMLESS EWS prioritises advanced materials in early stages of innovation based on "warnings flags". This pre-assessment framework was recently published at (<https://doi.org/10.1002/adsu.202500217>).

## 8.5 Italy

Italy coordinates the European project INTEGRANO (Jan 2024-Dec 2027, HORIZON-CL4-2023-RESILIENCE-01-22, within the topic "Integrated approach for the impact assessment of safe and sustainable chemicals and materials – RIA"). The INTEGRANO project consortium, consisting of 13 partners from 8 countries, is developing an integrated quantitative methodological approach to assess the safety and sustainability of nanomaterials in real-case life cycle scenarios. The INTEGRANO methodology is aligned with the JRC SSbD framework and encompasses four stages of the nanomaterial life cycle: synthesis, incorporation, utilisation and end-of-life, evaluating performance across five dimensions – safety, environmental, economic, social and function.

Within the project a wide range of nanomaterials (Surface-functionalised silver nanoparticles, silica and titania core-shell nanomaterials, Egyptian blue ( $\text{CaO} \cdot \text{CuO} \cdot 4\text{SiO}_2$ ), ZnO, CuO, doped perovskite oxides,

polymer nanofibers, bio-silica, C-dots) and nano-enabled products are under development with applications across different industrial sectors (textiles, water treatment, cosmetics).

The quantitative methodological assessment approach relies on the generation of dedicated response functions that enables the association of Key Decision Factors (KDFs, such as concentrations, processing parameters, etc.) to Key Performance Indicators (KPIs, such as occupational safety, CO<sub>2</sub> emissions, job creation potential, NM cost, antibacterial functionality, etc.). A bespoke digital Decision Support Toolbox (DST) has been developed to process the case specific data generated and run Multi Objective Optimisation Design (MOOD) algorithms to sort the set of multi-optimal SSbD options that meet the requisite levels of performance in each of the five dimensions. The DST can provide SSbD solutions based on the stakeholder profile, thus enabling the nanomaterials and nano-enabled products selected for development or application to be tailored stakeholder requirements.

A key innovation of the INTEGRANO project is the development of dedicated nanomaterials novel impact categories (ICs) for nano-toxicity and eco-nano-toxicity assessment. This enables the integrated application of standardised assessment methodologies and allows the determination of SSbD solutions based on case-specific data. The INTEGRANO project has also developed a bespoke data management tool to enable the management and curation of data according to the FAIR data principles. Within the data management tool, digital twins of the case studies being performed within the project are created, including detailed inputs related to the KDFs and KPIs within the case study. This provides a clear picture of the data to be collected within each case study and facilitates the structured collection data which complies with FAIR data principles and harmonised data sets.

In 2024 INAIL started a National Project in cooperation with Italian Institute of Technology, on “Nanotechnology and key enabling technologies: prevention-through-design and advanced sensors for airborne pollutants detection in the work environment (Nanokey Sens)”. The project has two major objectives: 1) to implement the Nanokey PtD framework in contexts of production of nanomaterials and new advanced materials also on an industrial scale; 2) to investigate the applications of nanotechnology-based sensors for the detection of airborne pollutants in the workplace. First results have been published in Natale et al. (2025) (<https://doi.org/10.1016/j.impact.2025.100555>).

## 8.6 The Netherlands

The **SUNSHINE-project** has developed an approach that enables safety and sustainability assessment at each stage of product development from a lifecycle perspective. This approach was presented in a [webinar](#). The [SUNSHINE e-infrastructure](#) is a digital platform implementing the Safe and Sustainable Innovation Approach. It facilitates exchange of ideas and information between supply chain actors as well as between innovators and regulators. A SUNSHINE foresight framework has been developed as a potential first step of Early4AdMa. This Foresight Framework is based on [published work](#) from JRC. A joint SUNSHINE-HARMLESS-OECD workshop discussed to what extent this Foresight Framework could be integrated into the Early4AdMa. Another [analysis](#) looked at how different EU regulations (e.g. REACH) cover multi-component nanomaterials.

The European project [IRISS](#) started in June 2022 and will finalise by end of May 2025. The project forms an international ecosystem for accelerating the transition to Safe-and-Sustainable-by-Design materials, products and processes. The project has two main goals. First it will develop an EU led SSbD International community. Secondly it will develop SSbD roadmaps for the practical application of SSbD. These roadmaps focus on needs for research, skills, competences and education, and on knowledge and information sharing. Within IRISS, there are seven value chains involved: automotive, construction, electronics, energy, fragrances, packaging and textiles. Several outcomes have now been published. A first step towards a common understanding and value chain perspective aims to bring SSbD closer to practical applicability (doi: [10.1016/j.cogsc.2023.100876](https://doi.org/10.1016/j.cogsc.2023.100876)). The SbD landscape was mapped for SSbD

applicability (doi: [10.1016/j.envint.2023.108305](https://doi.org/10.1016/j.envint.2023.108305)), and building blocks of the SSbD concept were identified (doi: [10.1007/s42398-024-00324-w](https://doi.org/10.1007/s42398-024-00324-w)). A roadmap for SSbD needs (doi: [10.1039/D4SU00310A](https://doi.org/10.1039/D4SU00310A)) and ways to address identified challenges were published as well (doi: [10.1093/inteam/vjae031](https://doi.org/10.1093/inteam/vjae031)), next to views on bringing SSbD closer to practice (doi: [10.1039/D4SU00809J](https://doi.org/10.1039/D4SU00809J)). To bring everything together, a [platform](#) was launched on May 2024 to connect the IRISS community and accelerate the industrial transition with SSbD. In this platform, users can discuss topics around SSbD, connect in value chains, and find value-chain-specific information and guidelines about SSbD. This platform will remain active beyond the IRISS-project duration.

[SbD4Nano](#) has been an industrially oriented project, where recognised research and technology organisations in nanosafety cooperate with SMEs and large industries to validate specific case studies. These case studies implemented new Safe-by-Design (SbD) approaches and tools relevant for nanomaterials. TNO (the Netherlands) was involved in almost all work packages and lead the work on 'Safe by Process Design: Exposure assessment and Risk Management'. The project ended in 2024 and delivered a new [e-infrastructure](#) to foster dialogue and collaboration between all actors in the supply chain. This provided a knowledge-driven definition of SbD setups that minimise hazards while optimising technical performances and economic costs. The e-infrastructure was tested in various industry case studies. TNO has developed the Nano Exposure Quantifier ([NEQ](#)), which is an online quantitative exposure assessment tool. It is designed to assist users in the safe-by-design process and decisions to reduce risk as a result from working with manufactured nanomaterials. The NEQ offers a tiered approach by adapting the questions based on the depth of information the user can provide. As part of the SbD module within the SbD4Nano e-infrastructure, the NEQ was integrated with risk management measures effectiveness and performance, resulting in informative e-cards. This integrated approach allows a pre-emptive cost-conscious exposure-driven safe-by-process-design modelling framework as key outcome.

[HARMLESS](#) provides novel tools, guidance and decision support for balancing functionality versus risk and ensure that the next generation nanomaterials will be harmless. The project finished in April 2025 and delivered a novel, multifaceted Safe Innovation Approach to multi-component nanomaterials (MCNMs) and high-aspect-ratio nanomaterials (HARNs). This approach integrates a toolbox of New Approach Methodologies. TNO (the Netherlands) lead the work on 'Tool Development', which built a user friendly SSbD Decision Support System for complex HARNs and MCNMs. TNO integrated existing methods from previous SbD projects with newly developed methods and components from the HARMLESS project into a **user-friendly SSbD decision support system** (DSS). TNO applied artificial intelligence and bioinformatics tools for data and model integration. HARMLESS developed an improved workflow for the early innovation stages, integrating three new tools and approaches in the decision support system. The tools are introduced as acronyms AMEA, WASP, and ASDI. AMEA (Advanced Material Earliest Assessment) helps in early categorisation, design principal advice and an applicability check. WASP (Warning flags, design Advice, Screening Priorities) raises points of attention and provides design advice and assessment advice. ASDI (Alternative SSbD Design Inspector) provides insight into the differences between different SSbD design versions within the various dimensions (safety, sustainability and performance). These insights can help industrial innovators to make an informed decision for the most optimal SSbD version.

The new EU project [PLANETS](#) will demonstrate safe-and-sustainable-by-design (SSbD) in industrial applications by developing, together with industry, alternative plasticisers, flame retardants and surfactants that are safe and sustainable by design. TNO is leading the work on SSbD decision support for successful substitution, the integration of safety and sustainability, and SSbD assessments for flame retardant alternatives. The project started in 2025. Initial activities consist of selecting and integrating existing information. This includes safety and sustainability methods and tools, the mapping of the flame-retardant case study, and refining existing software tools for the initial SSbD screening.

The Safe-and-Sustainable-by-Design (SSbD) Policy International Network (**SPINE**, established by a group of EU member states in 2019) facilitates knowledge sharing and exchanging expertise between European

policy makers on the development of SSbD. Current participating countries are Austria, Belgium, Denmark, Estonia, Germany, Greece, Netherlands, Spain, Sweden, Switzerland, and the UK. Other EU countries are invited to join the SPINE network. SPINE is in close contact with the European Commission (DGs GROW, ENV, RTD) in exploring opportunities for establishing a European centre that connects European networks and initiatives on SSbD (e.g. [JRC](#), [IRISS](#), [PARC](#), [NSC](#)) with national networks. Through these networks SSbD can be further linked to efforts on decarbonisation, circular economy and substitution of hazardous substances. From the start, SPINE members are participating in nanomaterials and advanced materials communities ([IAM-I and its predecessors](#), [OECD-WPMN](#), [ISO](#), [CEN](#), [ECHA-NMEG](#)). Recently SPINE presented its activities and a [synopsis](#) of its position paper in the meeting of CARACAL (Competent Authorities for REACH And Classification And Labelling).

## 8.7 Portugal

A recent project lead by the **National Institute of Health** (INSA, Lisbon, Portugal), focused on early-stage safety assessment of nanomaterials, using a Safe and Sustainable by Design approach. This project was in collaboration with the Department of Chemical Engineering of the Faculty of Sciences and Technology in **University of Coimbra** (Coimbra, Portugal) and with the **NOVA Medical School** (NOVA University of Lisbon, Portugal) and aimed at safety assessment of innovative cellulose nanomaterials (nanocelluloses). For this project, cellulose nanomaterials were produced with the support of University of Coimbra using industrial bleached *Eucalyptus globulus* kraft pulp. The investigation focused on applications that may lead to human ingestion, such as packaging for food, and intended to provide data on the potential safety concerns early in the innovation implementation, trying to identify the nanocellulose that would be safest to pursue product development. A PhD thesis has been submitted to the NOVA University, Lisbon Portugal on this work.

The **University of Aveiro** has a collaboration with industry for the development of novel materials for anticorrosion and antifouling products/formulations (collaboration with SmallMatek in Portugal),

The **International Iberian Nanotechnology Laboratory** (INL, Braga, Portugal), works on strategies related to SbD, and within this, lead the project SbDtoolBox - Nanotechnology-based tools and tests for Safer-by-Design nanomaterials, between 2020 and 2023 (<https://inl.int/projects/sbdtoolbox/>). SdDToolBox addressed the current general scarcity of methods and tools to obtain the relevant data encompassing the specific properties that differentiate nanomaterials from chemicals and paying special attention to the differential needs of the diverse impact and application areas, namely health, food or environment. In the frame of other projects were INL participates, such as NFFA and UPRISE, they are continuing working in strategies related to SbD.

The CeNTI - Centre for Nanotechnology and Advanced Materials (Vila Nova de Famalicão, Portugal), is involved in ASINA Project that aimed to develop an innovative methodology - ASINA-SMM - with scientific guidelines for creating safer and more sustainable nano-enabled products from the design stage. ASINA-SMM integrates digital tools, and nanomaterials' characterisation tools and data. CeNTI played an active role in developing a SSbD process for producing antimicrobial textiles by spray-coating application using nanomaterials. The new process minimises the use of chemicals and nanomaterials while maintaining the textile's performance and functionality, resulting in safer working conditions and a lower environmental impact. It is also a versatile process that is extendable to other industrial sectors that wish to leverage their products' safety and sustainability credentials. The project ended in February 2024, and has since resulted in the publication of two innovation reports based on the roadmaps developed in the scope of two of the case studies explored during the project:

- Furxhi, I., Perucca, M., Koivisto, A.J., Bengalli, R., Mantecca, P., Nicosia, A., Burrueco-Subirà, D., Vázquez-Campos, S., Lahive, E., Blosi, M., Lopez de Ipiña, J., Oliveira, J., Carriere, M., Vineis, C., Costa, A., *A roadmap towards safe and sustainable by design nanotechnology: Implementation for*

*nano-silver-based antimicrobial textile coatings production by ASINA project*. Computational and Structural Biotechnology Journal, 25 (2024) 127-142. <https://doi.org/10.1016/j.csbj.2024.06.013>

- Furxhi, I., Perucca, M., Baldi, G., Dami, V., Cioni, A., Koivisto, A.J., Bengalli, R., Mantecca, P., Motta, G., Carriere, M., Nicosia, A., Ravegnani, F., Burrueco-Subirà, D., Vázquez-Campos, S., Lahive, E., Lopez de Ipiña, J., Oliveira, J., Cronin, P., Blosi, M., Costa, A., Advancing titanium dioxide coated photocatalytic depolluting surfaces: *Leveraging ASINA's roadmap for safer and sustainable solutions*. Computational and Structural Biotechnology Journal, 25 (2024) 269-280. <https://doi.org/10.1016/j.csbj.2024.10.001>

The Innovation Radar, a European Commission initiative that identifies technological solutions with high innovation potential, also distinguished **CeNTI** as a "Key Innovator" for its scientific contribution within the scope of the European ASINA Project.

The INTEGRANO project aims to establish a multidimensional integrated approach to assess the safety and sustainability of nanomaterials throughout their life cycle, with a particular focus on nano-specific impact categories. Running from January 2024 to December 2027, the project brings together 13 partners from 8 countries, including CeNTI, to develop innovative solutions for more sustainable and high-performance materials. CeNTI plays a key role in the development and optimization of advanced nanomaterials, specifically  $\text{SiO}_2 @\text{TiO}_2$  and  $\text{bio-SiO}_2 @\text{TiO}_2$ , for application in eco-friendly coatings. The main focus is on sustainable synthesis and functionalization, exploring green processing routes to obtain nanomaterials with enhanced photocatalytic and antimicrobial properties. Additionally, CeNTI is responsible for the characterization and performance evaluation of these materials, ensuring their stability, efficiency, and applicability in functional coatings. Another critical aspect is the integration of these nanomaterials into coatings, guaranteeing their compatibility with scalable and sustainable application processes that contribute to the development of self-cleaning and antimicrobial surfaces.

## 8.8 Switzerland

The Federal Office for the Environment is financing a research project to develop two methods for evaluating the results of SSbD assessments. The first method aims to take data quality and uncertainty into account in order to inform chemical substitution within the SSbD framework. The second method aims to incorporate chemical functionality and uses in order to better address planetary trade-offs and prevent regrettable substitution through SSbD assessments. Both methods will then be integrated into the PARC toolbox, which was developed through the 'Partnership for the Risk Assessment of Chemicals'."

Switzerland (i.e. Federal Laboratories for Materials Science and Technology) organized an international SSbD conference with great success (10.-15. November 2024, Monte Verità). The follow-up is planned again in Switzerland for November 2025 close to Zurich.

The creation of a 'National Network SSbD Switzerland' is being evaluated. An initial exchange between Swiss Federal Agencies has been organised to gain an overview of all national activities in this area, and to plan possible future activities to promote operationalisation and awareness in this field.

Within the Safe-and-Sustainable-by-Design Policy International Network (SPINE), chaired by René Korenromp (Ministry of Infrastructure and Environment, Netherlands), the Chemicals Division of the Federal Office of Public Health collaborated on a Position Paper - Synopsis "Towards Safe-and-Sustainable-by-Design Chemicals" (<https://zenodo.org/records/15229328>).

For more information, please visit our SPINE LinkedIn account: <https://www.linkedin.com/groups/13149319/>

## 8.9 Sweden

### 8.9.1 SPINE

The Safe-and-Sustainable-by-Design (SSbD) Policy International Network (SPINE, established by a group of EU member states in 2019, chaired by the Ministry of Infrastructure and Environment, Netherlands) facilitates knowledge sharing and exchanging expertise between European policy makers on the development of SSbD. SPINE members, including Sweden, actively participate in nanomaterials and advanced materials communities, such as the [OECD WPMN](#) and [ECHA NMEG](#). The Swedish Chemicals Agency collaborated on a [synopsis](#) and position paper, “*Towards Safe-and-Sustainable-by-Design Chemicals*”, presenting the SPINE activities, which was presented at the 54<sup>th</sup> CARACAL (Competent Authorities for REACH And Classification And Labelling) meeting in April, 2025. For more information, please visit the SPINE LinkedIn account: <https://www.linkedin.com/groups/13149319/>

### 8.9.2 NanoSafety2

The [NanoSafety2](#) project (“*Nanoparticles in Additive Manufacturing: Understanding Exposure-Induced Health Effects*”) is a 4-year interdisciplinary project (2023–2027) funded by KK-Stiftelsen and coordinated by Örebro University, designed to address the emerging occupational health risks associated with (nano)particle emissions in additive manufacturing (AM, 3D printing). The project integrates four sub-projects: SP1 (Exposure) measures, collects, and characterizes (nano)particles in AM settings; SP2 (Mechanisms of Action) investigates biological responses to collected particles using in vitro and in silico methods; SP3 (Health) assesses long-term health impacts on exposed workers; and SP4 (Knowledge Transfer) ensures bi-directional communication with industry partners and dissemination of results.

### 8.9.3 HÄMAT

[HÄMAT](#) (Health- and Environmental Effects of Additive Manufacturing) was a research consortium funded by Vinnova and coordinated by SWERIM (The Metal Research Institute) and consisting of research institutes, universities, health care and industries working directly or indirectly with additive manufacturing (3D printing). Research was conducted over three separate projects, each spanning over several years, (HÄMAT 1-3) with several subprojects where the whole value chain was represented. In brief, researchers together with industry representatives studied additive manufacturing of both polymers and metals from many angles, including occupational exposures and emissions (with a special focus on nanoparticles), physical hazards, health effects, toxicological effects, ventilation needs, recycling of materials and the role of corporate health care. Several scientific papers have been published from the different subprojects and a final popular scientific report for the whole HÄMAT project is due to be published in June 2025.

### 8.9.4 IRISS

The H2020 project [IRISS](#) (“*The international ecosystem for accelerating the transition to safe-and-sustainable-by-design materials, products and processes*”, 2022-2025) is coordinated by the [Swedish Environmental Research Institute \(IVL\)](#). The stated aims are to connect, synergize, and transform the safe-and-sustainable-by-design community in Europe and globally towards a lifecycle approach, with a holistic integration of safety, climate neutrality, circularity, and functionality at an early stage of designing and manufacturing materials, products, and processes. The project has recently published a [new SSbD Roadmap](#).

### 8.9.5 HARMLESS

Three academic partners ([Karolinska Institute](#), [Lund University/NanoLund](#) and [Chalmers Industriteknik](#)) and one industrial partner ([Nouryon](#)) from Sweden have been involved in the EU Horizon 2020 project [HARMLESS](#) (“Advanced high aspect ratio and multicomponent materials: towards comprehensive intelligent testing and safe by design strategies”) to develop and advance adverse outcome pathway (AOP)-driven IATAs based on new approach methodologies (NAMs). The overall ambition was to offer novel tools, guidance as well as decision support for balancing functionality versus risk to ensure that next-generation nanomaterials are safe by design. The project ended in April 2025 and the final webinar summary and recording can be viewed [here](#). Swedish scientists have led and been involved in several papers summarizing results from the project, including:

- Hristozov et al. Next Generation Risk Assessment approaches for advanced nanomaterials: Current status and future perspectives. *NanoImpact*. 2024 Jul;35:100523. doi: <http://doi.org/10.1016/j.impact.2024.100523> Epub 2024 Jul 24.
- Tancheva et al. High-throughput screening data generation, scoring and FAIRification: a case study on nanomaterials. *J Cheminform* **17**, 59 (2025). <https://doi.org/10.1186/s13321-025-01001-8>

### 8.9.6 PINK

One academic partner from Sweden (IMM, Karolinska Institutet) is involved in the HEurope project [PINK](#) (“Provision of Integrated Computational Approaches for Addressing New Markets Goals for the Introduction of Safe-and-Sustainable-by-Design Chemicals and Materials”), which aims to introduce an open innovation platform for the industry, offering computational approaches for advanced materials and chemicals development, safety assessment, and Artificial Intelligence techniques for data searches.

### 8.9.7 nanoPASS

One academic partner from Sweden (Lund University) is involved in the HEurope project [nanoPASS](#) (Bridging the gaps in nanosafety for animal-free prediction of adverse outcomes), which aims to develop and validate a technology for resource efficient animal free prediction of nanomaterial and advanced material induced long-term adverse outcomes and demonstrate its applicability in regulatory and industrial setting.

### 8.9.8 NEP

One academic partner from Sweden (Lund University) is involved in the HEurope project [NEP](#) (NFFA-Europe PILOT for new research infrastructure schemes). The project aims to increase European competitiveness in nanosciences and nanotechnologies. In JA14 of NEP the partners are developing a platform allowing to better understand the phenomena occurring at the interfaces between nanomaterials and biological cells to support material scientists to design new materials with a safer approach.

### 8.9.9 Nanoparticles in the Construction sector – new materials, new health risks, new mitigation strategies

This multi-disciplinary AFA insurance funded project, coordinated by [Lund University](#), aims to identify the nanomaterials used to enhance e.g. concrete in the construction sector today and tomorrow, assess emission risks and toxicity of these materials, and communicate precautionary measures to the industry.

### **8.9.10 Handling of recycled aggregate materials**

This multi-disciplinary AFA insurance funded project, coordinated by [Lund University](#) will assess the emission- and exposure risks associated with handling of recycled aggregate materials (with and without engineered nanoparticles), a handling which will increase substantially with the increasing circular economy.

## **8.10 Switzerland**

The Federal Office for the Environment is financing a research project to develop two methods for evaluating the results of SSbD assessments. The first method aims to take data quality and uncertainty into account in order to inform chemical substitution within the SSbD framework. The second method aims to incorporate chemical functionality and uses in order to better address planetary trade-offs and prevent regrettable substitution through SSbD assessments. Both methods will then be integrated into the PARC toolbox, which was developed through the 'Partnership for the Risk Assessment of Chemicals'.

Switzerland (i.e. Federal Laboratories for Materials Science and Technology) organized an international SSbD conference with great success (10.-15. November 2024, Monte Verità). The follow-up is planned again in Switzerland for November 2025 close to Zurich.

The creation of a 'National Network SSbD Switzerland' is being evaluated. An initial exchange between Swiss Federal Agencies has been organised to gain an overview of all national activities in this area, and to plan possible future activities to promote operationalisation and awareness in this field.

Within the Safe-and-Sustainable-by-Design Policy International Network (SPINE), chaired by René Korenromp (Ministry of Infrastructure and Environment, Netherlands), the Chemicals Division of the Federal Office of Public Health collaborated on a Position Paper - Synopsis "Towards Safe-and-Sustainable-by-Design Chemicals" (<https://zenodo.org/records/15229328>).

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## **8.11 United Kingdom**

### **8.11.1 SUNSHINE**

SUNSHINE recently concluded in December 2024. The project is focused on generating protocols and tools to support safe and sustainability by design (SSbD) of multi-component nanomaterials or advanced materials. The project developed a Safe Innovation Approach e-infrastructure which is freely available online. These facilities safe and sustainable by design approaches, in line with the EU SSbD Framework, for advanced multicomponent nanomaterials. In comparison to other projects such as HARMLESS the framework is rather detailed. The e-infrastructure will be developed further in the project SUNRISE, which will bring together the SUNSHINE and HARMLESS approaches to provide more flexibility and functionality.

### **8.11.2 SPINE**

The Safe-and-Sustainable-by-Design Policy International Network (SPINE) is a network of European regulatory organizations that was established in 2019 where the HSE Science Division has been involved. SPINE's mission is to ensure a safe and healthy living environment and to promote and stimulate SSbD for new and emerging chemical substances and materials and products. The group is currently drafting a position paper and synopsis.

### **8.11.3 *The Sustainable Materials Innovation Hub***

The Sustainable Materials Innovation Hub within the University of Manchester and the Henry Royce Institute works at the interface between academia and industry to enable safe and sustainable materials innovations, particularly in plastics and their multi-materials. Providing advice, assessment and innovation assistance to organisations big and small, the team have assisted >600 companies in the past 6 years, with >100 substantive projects. With projects ranging from conveyor belt repair to circular credit cards to quality control in mechanical recycling, the team helps to quantify sustainability benefits of repair, reuse, recycling and depolymerisation of complex multi-materials, including products with embedded nanomaterials, across packaging, construction, healthcare and automotive sectors.

# 9 Additional Information

## 9.1 Thailand

Thailand will host the NANOTHAILAND 2025 conference from 3–5 November 2025 at the Royal Orchid Sheraton Riverside Hotel, Bangkok, where nanosafety and standards will be key themes.

## 9.2 The Netherlands

RIVM leads the development of SimpleBox. The SimpleBox group of models, which includes the **SimpleBox4nano** model has been updated from the spreadsheet version to a [new version](#) in R. This allows for improved dynamic and probabilistic environmental exposure assessments. The new version of SimpleBox4nano was recently applied for a multicomponent nanomaterial case study as part of the SUNSHINE project.