Project Deliverable Report

D1.3: Initial report on the nano-related EIROS safety
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* PU = Public  
PP = Restricted to other programme participants (including the Commission Services)  
RE = Restricted to a group specified by the consortium (including the Commission Services)  
CO = Confidential, only for members of the consortium (including the Commission Services)
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<td>Sheona Read, Gordon Fern</td>
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</tbody>
</table>
Table of Contents

1. Introduction .......................................................................................................................... 4
2. Objectives ............................................................................................................................ 4
3. Nanomaterial Hazard, Exposure and Risk ........................................................................... 5
   4.1 Overview of the approach ............................................................................................... 7
   4.2 Implementing the approach ........................................................................................... 9
   4.3 Good company practice .............................................................................................. 16
5. Best Practice Guidance for the Safe Handling and Use of Nanomaterials ..................... 18
   5.1 Safe handling ............................................................................................................... 21
   5.2 Control measures ......................................................................................................... 22
   5.3 Clean-up, spillages and accidental releases ................................................................. 25
   5.4 Storage & transport ..................................................................................................... 25
   5.5 Waste handling & disposal ........................................................................................ 26
6. Regulatory Compliance Management .............................................................................. 27
   6.1 Workplace safety and health legislation ...................................................................... 29
   6.2 Chemicals legislation ................................................................................................... 29
   6.3 Material-specific legislation ....................................................................................... 33
   6.4 Product-specific legislation ....................................................................................... 35
   6.4 End-of-life legislation .................................................................................................. 40
7. Initial Safety Survey of EIROS Partners ........................................................................... 43
   7.1 Scope & methodology ................................................................................................. 43
   7.2 Summary of survey responses ..................................................................................... 43
   7.3 Conclusion .................................................................................................................. 51
8. References ......................................................................................................................... 52
Appendix 1: Survey Monkey Questionnaire ...................................................................... 56
1. Introduction

Nanotechnology is one of the key enabling technologies supporting innovation in the 21st century. The field is growing rapidly, boosted by major national investments and commercial opportunities promising the development of new materials, processes and products utilising novel properties at the nanoscale. Whilst emerging technologies and cutting edge science provide opportunities they also carry risk, with uncertainties in the understanding of how these risks impact on human health and the environment. Innovation from effective exploitation of new technologies requires that these uncertainties are better understood and minimised through proportionate actions based on emerging evidence. Mitigating the potential risks to workers, consumers, and the environment is essential for the successful exploitation and commercialisation of research, new processes, technologies and products.

The EIROS project aims to develop self-renewing, erosion resistant and anti-icing materials for composite aerofoils and composite structures that can be adapted for different industrial applications, specifically: wind turbine blades and aerospace wing leading edges, cryogenic tanks and automotive facia. The addition of novel multi-functional additives to the bulk resin of fibre reinforced composites will allow the achievement of these advanced functionalities. With a view to supporting the responsible development and successful commercialisation of these innovations, EIROS is adopting a ‘safe by design’ approach informed by a number of tasks focused on early-stage evaluation and management of safety aspects associated with the materials, processes and components being used and developed as part of the project.

2. Objectives

The objective of Task 1.4 was to provide an initial report on the approach being adopted to evaluate and manage safety aspects associated with the nanomaterials, processes and components being used and development in the EIROS project.

In order to address this objective, and for the overall benefit of the technical project partners, this deliverable is structured into a number of sections which provide:

- An introduction to nanomaterial hazard, exposure and risk considerations (Section 3);
- A general risk management framework for nanomaterials and nano-enabled products (Section 4);
- A summary of best practice guidance for the safe handling and use of nanomaterials and nano-enabled products (Section 5);
- An introduction to regulatory compliance management for the materials and products being developed as part of the project (Section 6); and
- An overview of existing safety practices of the EIROS project partners, based on the findings of an online questionnaire (Section 7).
3. Nanomaterial Hazard, Exposure and Risk

The risk to human health as a result of exposure to a chemical is generally considered to be a function of the intrinsic harmfulness of the chemical (its toxicity) and the dose (amount) which accumulates in a specific biological compartment (e.g. the lungs). For occupational exposures, it is often very difficult to determine the dose directly, particularly in the case of insoluble particulates. Therefore, in order to measure and manage the risks, it is usual to assess exposure as a surrogate for dose. Occupational exposure to chemicals can occur via inhalation, dermal or ingestion routes. Control of exposure (to zero, or as low as reasonably practicable) effectively reduces the risks. Thus, regardless of how hazardous a substance is, without exposure there is no risk.

Hazard identification, realistic interpretation of dose-response relationships, and exposure assessment are critical steps in the process of risk assessment and management, as shown in Figure 1.

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**Figure 1:** The risk assessment paradigm relating hazard, exposure and risk (BSI, 2010)

Whilst engineered nanomaterials are the subject of increasing financial investment worldwide, and used in many industries, it has been recognised that they may also represent hazards to the health of workers, consumers or the environment. One of the first reports to highlight the potentially hazardous nature of nanomaterials was that of the The Royal Society and Royal Academy of Engineering (2004) which has since been followed by more than 100 major reviews and position papers discussing the potential risks to human health and to the environment from exposure to nanomaterials. Plausible toxicology issues for nanomaterials, which should be kept in mind when handling and using nanomaterials, include:

- **Solubility.** Some types of nanoparticles become more soluble as particle size decreases. This could imply increased bioavailability for particles previously considered to be insoluble.
• *Higher specific surface area*. One of the main reasons nanomaterials tend to be more reactive than their corresponding larger-scale equivalents is that, per unit mass, they have a much higher surface area.

• *Morphology (i.e. shape)-related toxicity*. Based on toxicological research on asbestos and other industrial fibres, the ‘fibre paradigm’ states that fibres which are bio-persistent in the lungs and longer than 15 - 20 \( \mu \text{m} \) with a diameter less than 3 \( \mu \text{m} \) are considered to be hazardous to human health. Some high aspect ratio particulate nanomaterials (HARN) (e.g. some carbon nanotubes, nanowires, nanoplatelets, etc.) meet this description and are therefore likely to persist in the lungs, if inhaled.

• *Increased translocation potential*. As a result of their small size, nanoparticles and other nano-objects can reach parts of biological systems which are not normally accessible by other larger particles.

Increased production and use of nanomaterials leads to the potential for increased exposures to workers, consumers and the environment. Human exposure to engineered nanomaterials and environmental release of these materials can occur during all stages of the nanomaterial life cycle, including:

• nanomaterial synthesis;
• manufacturing of intermediates;
• manufacture of finished products/articles;
• use (service life) of products/articles;
• end-of-life recycling, processing and disposal of products/articles.

Throughout the life cycle of a single nanomaterial, there are multiple exposure scenarios which may or may not occur depending on the processes and procedures involved in the manufacture, use and disposal of that material. Throughout these scenarios, the population exposed, the levels of exposure, the duration of exposure, and the nature of the material to which people are exposed (e.g. pristine material, composite, agglomerate etc.), are all different, as are the potential risks posed. Therefore, this warrants a requirement to implement a risk evaluation and management strategy based on potential exposure from the known or predicted scenarios.

4. General Risk Management Framework for Nanomaterials

In most countries, legislation related to the use of chemicals or other hazardous substances in the workplace requires employers to undertake a risk assessment to identify and manage exposure to hazardous substances in order to prevent ill health of both employees and others who could be exposed.
Several frameworks have been suggested for assessing and managing risks from particulate nanomaterials, all of which are based on a common risk assessment approach. For example, the International Organization for Standardization (ISO, 2011) has proposed a step-by-step approach for nanomaterial risk evaluation and management. The approach described in this deliverable closely follows this framework, with minor adaptations to make it more specific to the scope of the EIROS project.

Undertaking a thorough risk evaluation typically relies on having:

- good information about the hazardous nature of materials;
- good information about the effectiveness of control approaches, and;
- convenient and accessible ways to monitor exposure.

One of the difficulties in applying this approach to nanomaterials is that available information may be incomplete or incorrect. Such knowledge gaps introduce significant uncertainty into any risk assessment. In general, the greater the gaps in knowledge, the more cautious the risk management strategy should be.

### 4.1 Overview of the approach

The way in which a suitable risk evaluation and management process is implemented will depend on the specific company (in terms of its size and structure) and its position in the supply chain, as well as any regulatory requirements. It is recognised that many companies will have limited resources, and thus the use of existing information from within the company and wider supply chain about the nature and intended uses of the nanomaterial is encouraged.

The flowchart outlined in Figure 2 overleaf suggests an approach, albeit with some assumptions, that can be used to simplify implementation of the risk evaluation and management methodology. The approach encompasses the following six steps, described in further detail in Section 4.2:

1. Describe materials and applications;
2. Develop material profiles;
3. Evaluate risks;
4. Assess risk management options;
5. Decide, document and act;
6. Review and adapt.
Step 1. Describe materials & applications
- Identify & describe the nanomaterials being evaluated and their intended uses or functions (including potential benefits).
- Where required, identify analogous materials that might help address data gaps.

Step 2. Develop material profiles
- Develop sets of “profiles” including:
  i. the nanomaterial’s physico-chemical properties;
  ii. inherent environmental, health and safety hazards; and
  iii. potential human and environmental exposures throughout the nanomaterial’s lifecycle.
- The process of developing these profiles should also include identifying and prioritising data gaps, and deciding how to address such gaps (e.g. by collecting additional data or using reasonable worst case assumptions).

Step 3. Evaluate risks
- Information from the profiles should be evaluated to identify and characterise the nature and magnitude of the risks (i.e. combination of hazards and exposure) presented by particular nanomaterials and their anticipated applications.

Step 4. Assess risk management options
- Evaluate how to manage the risks identified in Step 3 and recommend a course of action.
- Options might include:
  ∷ Product or process modifications;
  ∷ Engineering controls;
  ∷ Protective equipment;
  ∷ Risk communication.

Step 5. Decide, document, & act
- Appropriate to the product’s stage of development, decide whether or in what capacity to continue development and production of the nanomaterial (or the process or product using the nanomaterial).
- Document decisions and their rationale.
- Where appropriate, share information with relevant (internal and external) stakeholders.
- If further information is needed, action should be taken to gather it.

Step 6. Review & adapt
- Through regularly scheduled reviews, as well as reviews triggered by specific events, it might be necessary to:
  ∷ update the risk evaluation;
  ∷ ensure that risk management systems are working as expected; and
  ∷ revise or improve those systems in response to new information or new conditions.

Figure 2: Step-by-step approach for nanomaterial risk evaluation and management (ISO, 2011)

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4.2 Implementing the approach

Step 1: Describe materials & applications

Gathering accurate information about the nanomaterials and their applications is a key step in the risk evaluation and management methodology. If little is known about the material, it is recommended to adopt a precautionary approach by treating the material as hazardous and applying strict risk management controls. Focus should be placed on the collection of information about the material, processes and work practices that can inform the risk assessment.

Examples of the type of questions to answer regarding the nanomaterials and their applications are provided below (ISO, 2011, ISO, 2012).

Questions to consider regarding the nanomaterial:

- What is the chemical composition?
- How and in what form (e.g. powder, agglomerated, pelletized) is the nanomaterial transported to your facilities?
- Is there a Safety Data Sheet (SDS) for this material?
- Do you have sufficient information to identify how hazardous or toxic the material is?
- Is there a larger-sized, or bulk, version of this nanomaterial on the market for comparison?
- How dusty is the material, how easily are particles released into the air?
- Are the particles long and thin?
- What is the particle size distribution?
- Is the material water soluble?
- How and in what form is the nanomaterial used?
- What volume of nanomaterial will be used on an annual basis?
- Are there materials which could be used instead of the nanomaterial that are potentially less hazardous, but still achieve the required end properties?
- Do you have access to sources of additional information on this nanomaterial?

Questions to consider regarding the application:

- What are the expected or intended applications of the nanomaterial?
- What new or different benefit does this nanomaterial offer compared to existing alternatives for the same product?
- How will you (and your employees or contractors) be handling, using or processing the nanomaterial?
- In what form will the nanomaterials be present in intermediate and final products?
- Will the nanomaterials be agglomerated physically or chemically bound in a matrix in the intermediate and final products?
- How will the products be handled when received by downstream processors and end-users?
• How much of the nanomaterial will be present in the intended products? What types and sizes?
• Are there applications for this nanomaterial that intentionally will not be pursued? How will the nanomaterials, intermediates and products be handled and disposed of, post-use?

It is important to document both the available information and the information gaps in order to inform the later stages of the risk evaluation.

Step 2: Developing material profiles

After gathering initial information on the nanomaterial and its applications, it may be necessary to undertake a more thorough identification and characterisation of the nanomaterial’s physico-chemical properties, inherent hazards and the exposures associated with its life cycle.

It is considered inappropriate to use data for the bulk material (e.g. silica, graphite, carbon, etc.) without any consideration of the validity of this information for the nano-form of the substance in terms of toxicology, exposure limits and control measures. When using Safety Data Sheets as a source of information these should be carefully assessed to ensure the information is representative of the nanomaterial in question.

A review of existing literature and information for the nanomaterial is recommended as a starting point to obtain characterisation, hazard and exposure data necessary to inform an adequate risk assessment. Key sources of information may include:

• ECHA Database on Registered Substances;
• ECHA Classification and Labelling Inventory;
• ESIS;
• GESTIS;
• eChemPortal;
• TOXNET;
• PubMed;
• Web of Knowledge.

Where there are gaps in available data, and it is not feasible to undertake new testing to fill these gaps, the information which is available in the literature may enable initial decisions to be made based on competent judgement. Alternatively, reasonable “worst case” assumptions should be made.

In relation to physico-chemical properties, the characteristics of the material should be understood not only in “free-form” (i.e. in its natural state), but also during the various phases of the material life cycle (after processing and incorporation into nanocomposite products, during use, service life and disposal of products). It might, therefore, be necessary to characterise the nanomaterial at multiple points in the life cycle, unless it can reasonably be expected that the nanomaterial will remain unchanged.
A suitable hazard profile would be one that characterises the nanomaterial’s potential intrinsic health, environmental and safety hazards over the entire life cycle of that material in the relevant application(s). Where there is limited specific hazard data for a particular nanomaterial, it may be possible to extrapolate or “read across” to an analogous material for which there exists robust hazard data for a particular end-point. For each lifecycle stage, as appropriate to the stage of development, creating a hazard profile typically involves:

i. Use of existing data;
ii. Prioritising data needs;
iii. Defining protocols and conducting appropriate testing;
iv. Characterising the hazard.

In terms of exposure, it is necessary to identify and characterise the potential for both human and environmental exposures across the full life cycle of the nanomaterial and nanocomposite products. Consideration should be given to the way in which the nanomaterial is incorporated into the product, as this may affect the potential for the nanomaterial to be released. A general process for developing an exposure profile for each life cycle stage would involve:

i. assessing the potential for releases of engineered nanomaterials;
ii. prioritising data needs;
iii. developing and implementing a plan to address these needs;
iv. characterising exposure.

As risk management and control measures affect exposure during manufacture, the following questions should be considered when developing an occupational exposure profile:

- What are the routes or opportunities for occupational exposure to nanomaterials?
- What engineering controls (e.g. ventilation, containment) are in place and how well are they performing?
- What personal protective equipment (e.g. safety glasses, gloves, overalls, masks) is in use?
- What procedures (including housekeeping and waste management) are in place to minimise exposure?
- How effective are the engineering controls and protective equipment with regard to the particular nanomaterial under consideration?

**Step 3: Evaluating the risks**

The earlier the potential risks are identified during the life cycle of the nanocomposite, the better the opportunities for effective risk mitigation and management.

The next step involves the assessment of risk, giving consideration to the physico-chemical properties, toxicity and exposure determinants to characterise the risk. The risk assessment may result in a qualitative, semi-quantitative, or fully quantitative estimate of the nature,
likelihood, and magnitude of effects on human health and the environment, depending on the stage of development and availability of relevant data.

Key steps in the first cycle of the risk evaluation process include:

i. Review hazard and exposure profiles

- Match exposure situations with hazards and compare potential exposure levels to published or derived effect levels (e.g. occupational exposure limits or NIOSH recommended exposure limits), where available;
- Understand the nature, magnitude, and likelihood of identified potential hazards and exposures.

ii. Evaluate the risk level and uncertainty

- Use the hazard and exposure information/data to conduct a quantitative or semi-quantitative risk assessment to generate a risk level. The application of safety factors should be considered to account for uncertainty or data gaps.
- Risk assessment models or control banding tools may be used to help determine the risk level.
- In the absence of adequate data, the risk assessment will be qualitative.

iii. Assess potential for and consequences of changes in material and applications

- It might be appropriate at this stage to take into account a variety of potential situations that might alter the likelihood, nature, or magnitude of potential risks.
- For example, considering how changing the supplier of the nanomaterials might cause subtle changes in the properties of the product at some stage of the life cycle.

iv. Identify knowledge gaps

- In the course of evaluating risks, there may be significant gaps in knowledge in relation to hazard and/or exposure. These can then be prioritised for further data gathering.
- For example, a nanomaterial-containing composite might pose little exposure risk until the composite starts to degrade. It might be difficult in the early stages of development to sufficiently characterise the nature of the degraded material, but this goal can be prioritised for further study (e.g. artificial weathering) prior to full commercialisation.

v. Develop a plan to fill data needs or identify “reasonable worst-case” scenarios for use as benchmarks in risk management

- If the data are insufficient at this point to adequately assess the potential risks, decisions should be made regarding the data gaps and how best to deal with them.
Step 4: Assessing risk management options

Risk management consists of actions to reduce and control risks from known and reasonably anticipated activities associated with the nanoproduct’s raw-material sourcing, manufacturing processes, transportation, expected uses and disposal, recycling, or re-use pathways. Key stages in the risk management process can be summarised as follows:

i. Determine required levels of protection

• Control measures should be appropriate for the identified risk. For example, it might be decided that working with nanoparticles fixed in an epoxy resin would require less restrictive levels of protection than working with nanoparticles in a dry-mixing operation.
• Decisions should be based on existing health, safety and environmental requirements, regulations and standards, and on the effectiveness of the chosen control method in reducing exposure to below a level determined acceptable.
• These decisions need to be made for each stage of the product life cycle.

ii. Identify the possible risk management options for reducing identified risks

• Undertake a formal and ongoing review of current risk management practices relevant to the manufacturing process, the product itself, and the transportation and use of the product.
• Measurement of exposures should be undertaken where appropriate and practical to inform an assessment of the effectiveness of risk management options.
• The review should also take into account: safety, health, environmental goals, policies, and procedures; applicable regulatory requirements; safe-handling practices; safety information from suppliers; customer feedback use and misuse of the product; and recycling and waste management.

iii. Determine best risk management options

• Evaluate the adequacy of existing risk management options, and the need to enhance or supplement them.
• The selected risk management options should adequately address existing and potentially new exposure situations.

iv. Develop a plan for risk management

• The plan should include monitoring, compliance and reporting which provides a means of determining and documenting that appropriate and effective systems are in place for managing potential risks throughout the nanomaterial’s life cycle.
The choice of the most appropriate actions will need to be made on a case-by-case basis depending on the specific situation under consideration. A widely recommended approach for risk management is that of the ‘hierarchy of control’, depicted in Figure 3, which recommends control measures in a priority order.

Guidance on appropriate control measures to employ during the handling, storage and disposal of nanomaterials is available from a number of national and international organisations, further discussed in Section 5 of this deliverable. In addition, a number of qualitative control banding approaches have been developed where specific controls are recommended based on a determined level of risk for a particular process, including those published by Safe Work Australia (SWA, 2012) and ISO (2014).

**Step 5: Decide, document and act**

This step of the process involves reviewing the previous compilations of data, analysing the options, making decisions for risk management and then documenting and acting on these decisions. The scope of information that is considered should be appropriate to the stage of development of the nanocomposite product.

Key steps in the review and decision-making process are as follows:

i. Involve a cross-functional decision-making team

- The size and composition of the team will depend on the nature of the organisation involved, the scope of the overall effort, and the stage of development.
- Ideally the team should include a broad cross-section of relevant viewpoints, including technical, manufacturing, workforce, business, and legal perspectives.
- Where feasible and appropriate, it may be beneficial to involve outside stakeholders early in the review and decision-making process to enhance the broader acceptability of the final product.
- Preferably the team will include persons with knowledge and experience in risk assessment, toxicology, environmental fate, and industrial hygiene.

ii. Review the risk assessment/ risk assessment plan

- Review the information that was collected and evaluated regarding the risks associated with development, manufacture, use, reuse/recycling, and disposal of the product, and the options to lessen, control or eliminate such risks.
iii. Consider any business, legal, and stakeholder issues

- Examples of considerations include new or emerging regulations, public perceptions, worker perspectives, liability concerns, potential for design changes to reduce risk, and the potential benefits (including any reductions in risks) associated with the use of the nanocomposite product.

iv. Designate who is responsible for implementing recommended actions

- An individual should be identified who is responsible to ensure that the recommendations of the review team are implemented.

v. Based on these inputs, decide whether and how to proceed

- Possible outcomes of the review team’s deliberations might include a decision to continue, terminate, redirect or modify the development, manufacture, use, or sale of the product involving engineered nanomaterials.

vi. Determine additional data needs and initiate data collection, as necessary

- Such data could include new physico-chemical, hazard or exposure data, or risk management information.

vii. Establish and implement appropriate risk management, monitoring, compliance, and communication processes

- The decisions made and the basis for those decisions should be documented, including a description of the technical results of the risk evaluation and risk management assessment and any assumptions made.
- Information relevant to occupational exposures, hazards, risks and controls should be communicated and made available to workers who research, develop, or manufacture the packaging product (e.g. through SDS and training).
- As products move into commercialisation, organisations should consider making relevant information available to a broader range of stakeholders.

**Step 6: Review and adapt**

In this step, a process of periodic and “as needed” reviews of the risk assessment(s) should be implemented to ensure that the information, evaluations, decisions, and actions regarding risk management remain effective and are kept up-to-date. As part of this process, new information should be identified and evaluated, and it should be determined whether the current risk evaluation or risk management practices need to be revised in light of the new information.

A risk management review should be undertaken whenever there is a significant change in hazard or exposure information, production volume, or use profile. In addition, a regular
schedule for periodically reviewing recent data and the adequacy of the current risk management process should be set and adhered to. As a result of the review, it may be necessary to make decisions or make recommendations on what actions should be taken and assign responsibilities for implementing these. Each review should be documented and any changes in the risk evaluation or risk management practices communicated to those who will be affected (e.g. workers, customers etc.). In some instances, updating the information might be required by law (e.g. updating SDS).

4.3 Good company practice

An approach to risk evaluation and management should form part of an overall strategy for the management of health and safety within an organisation. This should include giving consideration to broader aspects such as fire/explosion risks, health surveillance, spillage and emergency procedures, and disposal considerations (ISO, 2012). A useful approach, which treats health and safety management as an integral part of good company practice in general, has been outlined by the UK Health and Safety Executive (HSE, 2013a) and involves four key steps: Plan, Do, Check, and Act. This stepwise approach is depicted in Figure 4 and described in further detail below.

![Figure 4: The Plan, Do, Check, Act cycle (HSE, 2013a)](image-url)
**Plan**

- Determine your policy/plan for implementation
  - Think about where you are now and where you need to be.
  - Say what you want to achieve, who will be responsible for what, how you will achieve your aims, and how you will measure your success. You may need to write down this policy and your plan to deliver it.
  - Decide how you will measure performance. Think about ways to do this that go beyond looking at accident figures; look for leading indicators as well as lagging indicators.
  - Consider fire and other emergencies. Co-operate with anyone who shares your workplace and co-ordinate plans with them.
  - Remember to plan for changes and identify any specific legal requirements that apply to you.

**Do**

- Identify your risk profile
  - Assess the risks, identify what could cause harm in the workplace, who it could harm and how, and what you will do to manage the risk.
  - Decide what the priorities are and identify the biggest risks.
- Organise your activities to deliver your plan
  - Involve workers and communicate, so that everyone is clear on what is needed and can discuss issues – develop positive attitudes and behaviours.
  - Provide adequate resources, including competent advice where needed.
- Implement your plan
  - Decide on the preventive and protective measures needed and put them in place.
  - Provide the right tools and equipment to do the job and keep them maintained.
  - Train and instruct, to ensure everyone is competent to carry out their work.
  - Supervise to make sure that arrangements are followed.

**Check**

- Measure your performance
  - Make sure that your plan has been implemented – ‘paperwork’ on its own is not a good performance measure.
  - Assess how well the risks are being controlled and if you are achieving your aims.
    - In some circumstances formal audits may be useful.
- Investigate the causes of accidents, incidents or near misses

**Act**

- Review your performance

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This project has received funding from the European Union’s Horizon 2020 Research and innovation programme under grant agreement N° 685842
o Learn from accidents and incidents, ill-health data, errors and relevant experience, including from other organisations.
o Revisit plans, policy documents and risk assessments to see if they need updating.
• Take action on lessons learned, including from audit and inspection reports

Companies are encouraged to have an integrated approach to product stewardship, supply-chain management, occupational health and safety, quality management and/or environmental management and have:

• a specific individual or team in the company with designated responsibility for implementation of the risk evaluation and management process;
• personnel from business development, marketing, and regulatory affairs roles, along with relevant production workers involved in the decision-making process;
• a person competent in risk assessment, understanding (eco)toxicology and occupational safety data.

5. Best Practice Guidance for the Safe Handling and Use of Nanomaterials

Numerous organisations have published best practice guidance for the safe handling and use of nanomaterials. Current guidance recognises the risks involved in the development, manufacture, use, clean-up and disposal of nanomaterials in order to develop and implement effective precautionary strategies and adequate control measures to minimise potential inhalation, dermal and ingestion exposure.

Table 1 overleaf provides an overview of freely-available guidance documents for the safe handling, storage and disposal of various types of engineered nanomaterials. This includes guidance documents from the following organisations:

• British Standards Institution (BSI);
• Environment Agency (EA);
• European Commission (EC);
• Federal Institute for Occupational Safety and Health (BAuA);
• Health and Safety Executive (HSE);
• Institut de Recherche Robert-Sauvé en Santé et en Sécurité du Travail (IRSST);
• International Organization for Standardization (ISO);
• Nanosafe;
• National Institute for Occupational Safety & Health (NIOSH);
• Organisation for Economic Co-operation and Development (OECD);
• Safe Work Australia (SWA);
• UK Nanosafety Group (UKNSG).

This project has received funding from the European Union’s Horizon 2020 Research and innovation programme under grant agreement N° 685842
For each document, an indication is provided of whether it provides guidance in relation to:

- **A specific nanomaterial type:**
  - Nanomaterials (NM) in general;
  - Metal (M)/metal oxide (MO) nanomaterials;
  - High aspect ratio nanomaterials (HARN);
  - Carbon nanotubes (CNT) and/or carbon nanofibers (CNF);
  - Nano-platelets;
  - Graphene family nanomaterials (GFN).

- **A specific stage of the nanomaterial life cycle:**
  - Handling;
  - Storage; and/or
  - Disposal.

Based on these resources, a short summary of key best practice guidance is provided in the following sub-sections relating to: safe handing; control measures; clean-up, spillages and accidental releases; storage and transport, and; waste handling and disposal.
Table 1: Overview of available guidance documents for various types of nanomaterials

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<tr>
<th>Guidance Document Title</th>
<th>Organisation (Date)</th>
<th>NM in general</th>
<th>M/ MO HARN</th>
<th>CNT/ CNF Nano-platelets</th>
<th>GFN Handling</th>
<th>Storage</th>
<th>Disposal</th>
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<tbody>
<tr>
<td>Disposal of Manufacturing Process Waste containing MNO (BSI PAS 138)</td>
<td>BSI (2012)</td>
<td>✓</td>
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<td>Working Safely with Manufactured Nanomaterials – Guidance for Workers</td>
<td>EC (2014a)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Guidelines for Occupational Risk Management Applied to Nanomaterials (ISO 12901-1)</td>
<td>ISO (2012)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Compilation of Nanomaterial Exposure Mitigation Guidelines Related to Laboratories</td>
<td>OECD (2010)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>Working Safely with Nanomaterials in Research and Development</td>
<td>UKNSG (2016)</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
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<tr>
<td>Approaches to Safe Nanotechnology</td>
<td>NIOSH (2009)</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
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<tr>
<td>Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes</td>
<td>NIOSH (2013a)</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
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<tr>
<td>Using Nanomaterials at Work - Including CNT and other HARN (HSG272)</td>
<td>HSE (2013b)</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
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</tr>
<tr>
<td>Safe Handling of Nanomaterials and Other Advanced Materials at Workplaces</td>
<td>NIOSH (2013b)</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
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<tr>
<td>Interim Advice on Wastes Containing Unbound CNT</td>
<td>EA (2008)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>Occupational Exposure to CNT and CNF</td>
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<td>✓</td>
<td>✓</td>
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<td>Safe Handling and Use of Carbon Nanotubes</td>
<td>SWA (2012)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Engineering Controls for Graphene Platelets during Manufacturing and Handling Processes</td>
<td>NIOSH (2011b)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tr>
</tbody>
</table>
5.1 Safe handling

Currently no regulatory occupational exposure limit (OEL) for engineered nanomaterials has been set. However, NIOSH have proposed Recommended Exposure Limits (REL) for:

- **Respirable carbon nanotubes and carbon nanofibres** - worker exposure should not exceed 1.0 micrograms per cubic meter (μg/m³) elemental carbon as a respirable mass 8-hour time-weighted average (TWA) concentration (NIOSH, 2013b);
- **Ultrafine (nano-scale) titanium dioxide** - worker exposure should not exceed 0.3 milligrams per cubic meter (mg/m³) as a TWA concentration for up to 10 hours per day during a 40 hour work week (NIOSH, 2011a), and;
- **Pigmentary titanium dioxide (particle size greater than 100 nm)** - worker exposure should not exceed 2.4 mg/m³ as a TWA concentration for up to 10 hours per day during a 40 hour work week (NIOSH, 2011a).

In addition, a number of companies have developed in-house exposure limits. There exists a degree of variability in the suggested limits, partly due to the data set upon which the exposure limit is based, but also the nature of the derivation process including what safety factors are applied. Despite this, it is clear that certain nanoparticles may be more hazardous than larger particles of the same substance. Therefore, it is important to be aware that existing OELs for a substance may not provide adequate protection from nanoparticles of that substance. Employers should seek to minimise worker exposure as far as reasonably practicable by using appropriate exposure control measures.

The quantity of nanomaterial handled will significantly influence exposure potential. It is therefore recommended to use the minimum quantity of nanomaterial required for a particular experiment or process, as well as minimising the number of people potentially exposed and the potential exposure time.

Handling nanomaterials in a ‘free particle’ state (e.g. powder form) should be avoided wherever possible. Where feasible, the material should be kept wet or damp to reduce the risk of it becoming airborne and it is recommended to avoid energetic processes (e.g. sonication) that might generate airborne dusts or aerosol. Handling tasks should not be performed on the open bench and a damp sheet of absorbent material should be placed below the balance when weighing out particulate nanomaterials. Continuous bagging is recommended for the collection of intermediate and final products and samples should be transferred between operations in sealed, unbreakable containers or via an automated process.

More broadly, it is recommended that appropriate steps should be taken to minimise worker exposure through the development of a risk management program and implementation of an exposure measurement and control strategy.
5.2 Control measures

Exposure should be controlled by applying protection measures appropriate to the activity and consistent with the hierarchy of control (Figure 3). The basis for the hierarchy is to eliminate the hazard when possible (i.e. substitute with a less hazardous material) or, if not feasible, control the hazard at or as close to the source as possible. Whilst substitution or elimination of nanomaterials is often not feasible, it may be possible to change some aspects of the physical form of the nanomaterial or process in a way that reduces nanomaterial release, including the use of appropriate control measures. Control measures, discussed in further detail below, should be maintained in good working order with a competent person undertaking frequent visual checks and examinations.

Isolation and enclosure

It is widely accepted that enclosure and isolation of the process can minimise the airborne release of nanomaterials into the air during handling, production and use. All operations in which there is a deliberate release of nanomaterials into the air should be performed in contained installations, or where workers are otherwise isolated from the process. All other processes involving the use of dry nanomaterials should be performed in enclosed installations where possible. An enclosed system is particularly recommended for activities like measuring raw or manufactured materials, pouring (including mixing) into or collecting from the producing or processing equipment, cleaning containers and waste processing, unless there is no potential for exposure. Enclosures and ventilation should be designed to take into account the gaseous and particulate properties of the nanomaterials being used, and ventilation and filtration of the enclosure is recommended, particularly if free or low level aggregated/agglomerated nanoparticles are handled.

Engineering controls

Wherever reasonably practicable, worker exposure to nanomaterials by all routes (inhalation, dermal, ingestion) should be eliminated or controlled through the use of engineering controls (e.g. process containment, local exhaust ventilation, general ventilation). However, it is recognised that engineering controls need to be applied prudently to ensure protection of workers without compromising production.

The selection of engineering control measures will depend on the requirements of each workplace, and should take into account the quantity and physical form of the nanomaterial as well as the task duration and frequency. It may be necessary for those working with nanomaterials to use a combination of methods to control exposure and risk. A number of organisations have published control banding approaches for nanomaterials, including SWA (2012) and ISO (2014), where specific controls are recommended for various generic tasks involving the handling of nanomaterials.

Broadly speaking, for handling small quantities of powders or liquid suspensions, use of a HEPA-filtered laboratory fume hoods, HEPA-filtered exhausted enclosure (e.g. glove box) or a
biological safety cabinet is typically recommended. For handling larger quantities, higher control measures are recommended such as the use of isolation techniques (e.g. dedicated ventilated room), process-based controls (e.g. laminar down-flow booth), and ventilated bag dumping stations are recommended.

Regular maintenance and performance testing of engineering control facilities should be undertaken to ensure adequate protection of workers is sustained.

**General exhaust ventilation**

General ventilation by dilution in the work environment has the potential to draw contaminants outwards and, if it is the only engineering control utilised, might allow significant exposure of workers to nanoparticles. It is thus important that facilities where nanomaterials are handled have sufficient general exhaust ventilation; however it should not be the sole means of controlling exposure. Extracted air should not be recirculated without exhaust air purification. A well-designed exhaust ventilation system with a HEPA-filter should be installed to effectively remove nanoparticles.

**Local exhaust ventilation and fume cupboards**

Using selected forms of local exhaust ventilation (LEV) properly is widely considered to be appropriate for control of engineered nanomaterials. In general, full enclosures (e.g. a glove box with HEPA filtration) are considered to be the most effective. However, it is recognised that they can be impractical as a control option for some work processes and partial enclosures or flexible systems are therefore frequently used.

LEV systems should be designed, tested and maintained using established recommended approaches to ensure adequate control at all times. A well-designed LEV system should be fitted with a HEPA-filter to effectively remove nanoparticles. Exhaust air should never be recirculated into the workplace unless it has been effectively filtered to remove airborne nanoparticles by at least one HEPA filter. The duct velocity of the LEV should be maintained at 15-20 m/s to prevent migration of nanoparticles into the surrounding atmosphere.

In relation to fume cupboards, using double HEPA-filtered cabinets increases the level of worker protection and can provide a safe means of carrying out filter exchanges. It is important to recognise that the performance of air filters is affected by the aerosol characteristics including particle size, shape, concentration and electrical properties. Air filters should be routinely checked by monitoring the pressure drop, and replaced when high resistance is detected. A routine certification program should be established to monitor filter life and face velocity to assure that the filter performs as designed. It is also recommended to prepare written operating procedures for activities being carried out (e.g. replacement of HEPA filters, clean-up and spillages, waste disposal).
Administrative controls

Procedural and administrative means of control should be used to supplement and accompany engineering controls, not substitute them. It is consistently recommended throughout the available guidance to:

- minimise the number of employees handling nanomaterials, and minimise the level and duration of exposure and the quantities used;
- educate and train workers on the hazards of working with nanomaterials and the risks they pose, and the precautions that should be taken to avoid or minimise exposure, including the proper selection of personal protective equipment (PPE);
- provide facilities for hand-washing, changing clothes, showering and on-site laundering of contaminated work clothing to prevent inadvertent contamination;
- store work wear and private clothing separately;
- perform regular cleaning of the work area;
- avoid storing and consuming food or beverages in the workplaces where nanomaterials are handled.

Systems should be put into place to ensure that such administrative control measures are effective and are adhered to by workers.

Personal Protective Equipment and Respiratory Protective Equipment

Personal protective equipment (PPE) and respiratory protective equipment (RPE) should be utilised as a last option or supplementary option to help support the other methods of exposure controls. Incorrect selection, fitting or use of PPE and RPE can render it ineffective. Investment should be made in training, supervision and maintenance to ensure PPE and RPE provides the intended level of protection.

It is important to recognise:

- the level of PPE worn by operators working on the specific activities and identify other workers that may inadvertently be exposed;
- that engineered nanomaterials may persist in the atmosphere for a significant duration after the activities, including those activities within fume cupboards.

Protective clothing should ideally be made from air-tight fabrics made of non-woven textiles; cotton, wool or knitted materials are not recommended. If clothing is re-usable, regular laundering is advised to prevent secondary exposure. Closed toe shoes, made of a low permeability material, are recommended to be worn, along with disposable, over-the-shoe booties to prevent tracking of nanomaterials out of the work area. Two layers of single-use, disposable neoprene or nitrile gloves are recommended and these should fit the wearer correctly and cover the wrists. Gloves should be inspected for visual wear and tear and changed regularly, and special attention should be given to the proper removal and disposal of gloves to prevent skin contamination. Suitable eye protection should be worn; as a minimum, close-fitting safety glasses are advised.
Where RPE is required, appropriate steps should be taken to minimise worker exposure through the development of a complete respiratory protection program, including:

- **Respirator Selection** - the type of respirator should be chosen to reflect the nature of the hazard;
- **Medical Evaluation** - a medical evaluation is often used to determine the employee’s ability to use a respirator;
- **Face-Fit Testing** - face-fit testing is strongly recommended to ensure effectiveness of RPE on an individual basis;
- **Respirator Training** - recommended for all staff using respirators. It should be comprehensive, understandable and recurring.

The choice of respirator type will depend on the specific task and materials being handled. Several classes of respirators exist that can provide different levels of protection when properly fit tested on workers. Appropriate types of RPE mentioned in current guidance include disposable filtering face-pieces, half and full facemasks, and a range of powered (air supplied) hoods, helmets, blouses and suits.

### 5.3 Clean-up, spillages and accidental releases

Work areas should be cleaned regularly to limit accumulation of nanomaterials on work surfaces and to reduce contamination of the wider work environment. It is recommended that cleaning should be undertaken at the end of each shift, as a minimum, and performed using either a HEPA-filtered vacuum cleaner and/or wet-wiping using a damp cloth or wetting the materials before wiping. Energetic cleaning methods such as dry sweeping or the use of compressed-air hoses should be avoided or only used with precautions. Absorbent walk-off mats placed at the entry points of the work area can help to minimise the spread of nanomaterials. Consideration should be given to the proper selection and wearing of PPE during clean-up procedures.

Due to the potential for spillages and accidental releases, employers should have documented policies and procedures in place which, as far as possible, cover both smaller and more significant events. A spill kit should be made available for quick response to nanomaterial spillages and accidental release to minimise exposure. Only trained competent personnel authorised to deal with spillages and accidental release of nanoparticles should enter the affected area.

### 5.4 Storage & transport

A plan for storage and transport of nanomaterials or nanomaterial-contaminated waste should be developed, taking account of the hazard profile of the materials and the quantities involved.
Packaging of nanomaterials for storage or transport should be carried out in a fume-type hood system fitted with a HEPA-filter to reduce worker exposure. Dispersible nanomaterials, whether suspended in liquids or dry particle form, should be stored and transported in closed (tightly sealed) robust containers whenever possible. Containers should be unbreakable and labelled to indicate the chemical content and form of the nanomaterials. It is recommended that secondary containment (i.e. double bagging or bottles inside robust plastic outer containers) capable of withstanding foreseeable impacts should also be used. Precautions should be taken during transport in order to prevent accidental spillage. For shipping, nanomaterials should be packaged, marked, and labelled using approved packaging/containers and in accordance with the relevant technical instructions and transport/shipping regulations.

A standardised approach to labelling and safety signs for use with nanomaterials does not currently exist. In the absence of further information, it is broadly recommended that a diligent and precautionary approach to labelling and signage is taken. For example, existing risk and safety phrases and warning signs should be used provide adequate, relevant and specific information on any actual or potential hazards and safety risks. In the workplace, signage or pictograms should be posted in areas where nanomaterials are being handled or stored to indicate the hazard, PPE requirements and any other pertinent information.

5.5 Waste handling & disposal

A precautionary approach should be taken to handling nanomaterial-containing waste, such that all nanomaterial waste should be disposed of and treated as “hazardous waste”. Any materials or equipment that have come into contact with nanomaterials, and all debris resulting from the clean-up of a spillage or accidental release, should be considered as nanomaterial-containing waste and disposed of accordingly.

Waste should be managed in such a way that minimises exposure of those handling the waste to the nanomaterial component. It is recommended that transfer of nanomaterial waste into containers for subsequent disposal should be carried out inside a fume hood and appropriate PPE should be used during waste handling. Waste containers should be robust, sealed, and clearly labelled, providing a description of the waste and the (known or suspected) hazardous properties.

Disposal of nanomaterial-containing waste should be undertaken in accordance with local and national regulatory requirements for waste management. For safe disposal, the transport of nanomaterial-containing waste should be carried out by a registered waste carrier at a permitted waste management facility.
6. Regulatory Compliance Management

Successful introduction of new materials and products onto the marketplace is contingent on compliance with regulatory requirements. Failure to understand and comply with regulatory requirements has the potential to result in delays to product commercialisation or even financial and/or legal ramifications should crucial regulation unknowingly be overlooked.

Significant work is on-going at national and international levels to determine the extent to which nanomaterials and nanotechnology-enabled products fall within existing regulatory frameworks, and the adequacy of these frameworks for managing potential risks. A vital aspect of the successful and responsible development and commercialisation of nanomaterials and nanotechnology-enabled products is sustained awareness of regulatory developments and a pro-active approach to ensuring compliance. It is therefore important that a preliminary identification and scoping of regulatory requirements in key target markets is undertaken at an early stage in the development of nanomaterials and nanotechnology-enabled products as part of an overall safe by design approach.

Identification and scoping of regulatory requirements should follow a tiered approach and cover:

- Workplace safety and health legislation;
- Overarching chemical legislation;
- Material-specific legislation;
- Product-specific legislation.

Within each of these areas, particular attention should be paid to identifying current and (where possible) future requirements for regulatory compliance including relevant information requirements, trigger threshold volumes, and any relevant exemptions.

At a European level, the main regulatory instruments concerning safety aspects considered to be of relevance to the commercial sectors of interest within the EIROS project – namely aeronautic, astronautic, automotive, and wind energy - are summarised in Figure 5 and briefly described below. Country-specific legislations and procedures at local, regional and national level (including reporting schemes) may also apply and these should be investigated by individual companies. EU standards and best practice guidelines for design, operation and maintenance should also be taken into account, where relevant.
This project has received funding from the European Union’s Horizon 2020 Research and innovation programme under grant agreement N° 685842

Figure 5: Key EU legislation of relevance to the aeronautic, astronautic, automotive, and wind energy sectors.
6.1 Workplace safety and health legislation

Occupational Safety & Health Framework

Protection of workers health and safety from possible risks inherent to exposure to nanomaterials and/or nanotechnology use is by default covered by the current EU Occupational Safety and Health (OSH) Framework. Such coverage is essentially provided for by Framework Directive 89/391/EEC (EC, 2008a) on the introduction of measures to encourage improvements in the safety and health of workers at work, which is supported by a number of more specific individual directives. This Directive introduces measures to encourage improvements in the safety and health of workers in the workplace and specifies a number of general principles of prevention for protecting workers health and safety:

- avoiding risks;
- evaluating the risks;
- combating the risks at source;
- adapting the work to the individual;
- adapting to technical progress;
- replacing the dangerous by the non- or the less dangerous;
- developing a coherent overall prevention policy;
- prioritising collective protective measures (over individual protective measures);
- giving appropriate instructions to the workers.

At present, there are no specific provisions for nanomaterials in European worker protection legislation. However, a study was commissioned in 2011 at the request of the European Commission (EC, 2011b) to establish the potential impact of nanomaterials and nanotechnology at the workplace, evaluate the scope and requirements of possible modifications of relevant EU safety and health at work legislation (including Framework Directive 89/391/EEC and some of its supporting directives), and elaborate a guidance document to accommodate identified risks and concerns. As an outcome of this study, two guidance documents for those working with nanomaterials have been published by the European Commission, one aimed specifically at those handling nanomaterials in the workplace (EC, 2014a) and the other aimed at employers (EC, 2014b).

6.2 Chemicals legislation

Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

The overarching European chemicals regulation is ‘REACH’ (Regulation (EC) No. 1907/2006), concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals, which entered into operation in June 2008 (EC, 2006). REACH lays down provisions on substances manufactured or imported into the EU in quantities of 1 tonne per year or more. It covers substances on their own, in a mixture, or in an article manufactured, imported, placed on the
market or used. Definitions of key terminology used under REACH are provided in Table 2 below.

Table 2: Key definitions in accordance with the REACH Regulation

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Article</td>
<td>An object which during production is given a special shape, surface or design which determines its function to a greater degree than does its chemical composition.</td>
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<tr>
<td>Distributor</td>
<td>Any natural or legal person established within the Community, including a retailer, who only stores and places on the market a substance, on its own or in a mixture, for third parties.</td>
</tr>
<tr>
<td>Downstream user</td>
<td>Any natural or legal person established within the Community, other than the manufacturer or the importer, who uses a substance, either on its own or in a mixture, in the course of his industrial or professional activities. A distributor or a consumer is not a downstream user.</td>
</tr>
<tr>
<td>Importer</td>
<td>Any natural or legal person established within the Community who is responsible for import.</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Any natural or legal person established within the Community who manufactures a substance within the Community.</td>
</tr>
<tr>
<td>Mixture</td>
<td>A mixture or solution composed of two or more substances.</td>
</tr>
<tr>
<td>Monomer</td>
<td>A substance which is capable of forming covalent bonds with a sequence of additional like or unlike molecules under the conditions of the relevant polymer-forming reaction used for the particular process.</td>
</tr>
<tr>
<td>Not chemically modified substance</td>
<td>A substance whose chemical structure remains unchanged, even if it has undergone a chemical process or treatment, or a physical mineralogical transformation, for instance to remove impurities.</td>
</tr>
<tr>
<td>Placing on the market</td>
<td>Supplying or making available, whether in return for payment or free of charge, to a third party. Import shall be deemed to be placing on the market.</td>
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<tr>
<td>Polymer</td>
<td>A substance consisting of molecules characterised by the sequence of one or more types of monomer units. Such molecules must be distributed over a range of molecular weights wherein differences in the molecular weight are primarily attributable to differences in the number of monomer units. A polymer comprises the following: (a) a simple weight majority of molecules containing at least three monomer units which are covalently bound to at least one other monomer unit or other reactant; (b) less than a simple weight majority of molecules of the same molecular weight. In the context of this definition a ‘monomer unit’ means the reacted form of a monomer substance in a polymer.</td>
</tr>
<tr>
<td>Product and process oriented research and development</td>
<td>Any scientific development related to product development or the further development of a substance, on its own, in mixtures or in articles in the course of which pilot plant or production trials are used to develop the production process and/or to test the fields of application of the substance.</td>
</tr>
<tr>
<td>Registrant</td>
<td>The manufacturer or the importer of a substance or the producer or importer of an article submitting a registration for a substance.</td>
</tr>
<tr>
<td>Substance</td>
<td>A chemical element and its compounds in the natural state or obtained by any manufacturing process, including any additive necessary to preserve its stability and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition.</td>
</tr>
<tr>
<td>Supplier</td>
<td>Any manufacturer, importer, downstream user or distributor placing on the market a substance, on its own or in a mixture, or a mixture, or an article.</td>
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</table>

REACH requires all companies manufacturing or placing a substance on the EU market in quantities of 1 tonne or more per year to register that substance with the European Chemicals Agency (ECHA). ‘Phase-in substances’ (existing substances listed on the European Inventory of Existing Commercial Chemical Substances) which have been pre-registered before December 2008 should be registered in accordance with tonnage-based registration.
deadlines. ‘Non phase-in substances’ (i.e. new substances) should be registered immediately before placing on the EU market.

Registration is the responsibility of the manufacturer or importer of the substance, and must be done jointly with other manufacturers and importers of the same substance through the appropriate Substance Information Exchange Forum (SIEF). Registration requires the submission of a dossier to ECHA containing hazard information and, where relevant, an assessment of the risks that the use(s) of the substance may pose and how these risks should be controlled.

Polymers are currently exempt from registration and evaluation under REACH. However, manufacturers and importers of polymers may still be required to register the monomers or other substances used as building blocks of the polymer, as these molecules are generally recognised as being of higher concern than the polymer itself. Further guidance for monomers and polymers is available from ECHA (2012).

At present there are no provisions in the REACH legal text referring specifically to nanomaterials. However, REACH deals with substances, in whatever size, shape or physical state, and thus substances at the nanoscale are covered by REACH and its provisions apply. Following a scientific and evaluation under the ‘REACH Implementation Projects on Nanomaterials’ (RIP-oNs), the technical guidance documents supporting the REACH Regulation have been updated where necessary to provide guidance for those registering nanomaterials. A consultation is currently underway regarding potential modification of the REACH Annexes (and their associated regulatory requirements) regarding nanomaterials. Further guidance on nanomaterials under REACH is available on the ECHA website (http://echa.europa.eu/regulations/nanomaterials).

The responsibility for registering substances (including nanomaterials) in the aeronautic, astronomic, wind energy, and automotive supply chains falls on those who directly manufacture or import these substances at quantities of 1 tonne or more per year. Provided no chemical reaction takes place during the blending/compounding of a nanomaterial into a polymer matrix, the resultant nanocomposite masterbatch would be regarded as a mixture under REACH. Thus, the company producing the nanocomposite masterbatch would be regarded as a ‘formulator’ (a type of downstream user) under REACH. They would only have registration responsibilities if they directly synthesise or import any of the component substances which go into the nanocomposite.

Finished components for use in the aeronautic, astronomic, wind energy, and automotive sectors may be considered to be an ‘article’ under REACH. Deciding when in its life cycle a material has stopped being a substance/mixture and has become an article can be difficult (HSE, 2014). It is the responsibility of the manufacturer/importer to decide whether they are dealing with an article (where the shape, surface or design is most important) or a substance/mixture (where chemical composition is most important). There is no requirement to register articles under REACH, however the substance(s) within that article may be subject to registration requirements.
Further information and guidance on the REACH Regulation is available on the ECHA website (http://echa.europa.eu/web/guest/regulations/reach/).

**Classification, Labelling & Packaging (CLP)**

Regulation (EC) No 1272/2008 on the Classification, Labelling and Packaging (CLP) of substances and mixtures (EC, 2008e) entered into force in January 2009 and introduces the United Nations Globally Harmonised System (UN GHS) for classification and labelling (C&L) of chemicals into Europe. Its aim is to ensure that the hazard presented by chemicals is clearly communicated to workers and consumers in the EU.

Under this Regulation, before placing chemicals on the market, suppliers must establish the potential risks to human health and the environment of such substances and mixtures, classifying them in line with the identified hazards. The hazardous chemicals also have to be labelled according to a standardised system so that workers and consumers know about their effects before they handle them. Thus, the hazards of chemicals are communicated through standard statements and pictograms on labels and safety data sheets. Classification and labelling (C&L) of hazardous substances should be notified to ECHA within one month of placing the substance on the market for the first time. ECHA has established a classification and labelling inventory (http://echa.europa.eu/information-on-chemicals/cl-inventory-database), containing the information provided in accordance with the regulation.

The EC (2009a) published a document on the "Classification, Labelling and Packaging of nanomaterials in CLP and REACH". It is stated that nanomaterials that fulfil the criteria for classification as hazardous under the CLP Regulation must be classified and labelled. This applies to nanomaterials as substances in their own right, or nanomaterials as special forms of the substance. European manufacturers, importers, and downstream users of nanomaterials and nanocomposites classified as hazardous under CLP should therefore:

- classify, label and package substances and mixtures according to CLP before placing them on the market;
- notify the C&L to ECHA;
- update labelling following any change to the C&L of that substance or mixture;
- submit a proposal to the relevant Competent Authority if they have new information which may lead the change of harmonised C&L;
- provide SDS along the supply chain and update them when necessary.

Further information and guidance on CLP is available on the ECHA website (http://echa.europa.eu/web/guest/regulations/clp).
6.3 Material-specific legislation

Definition of the term nanomaterial

The EC has undertaken two regulatory reviews on nanomaterials, assessing the adequacy and implementation of EU legislation for nanomaterials (EC, 2008b, EC, 2012b). Although it has been concluded that nanomaterials are in principle covered by the various existing regulatory frameworks, the EC have acknowledged that there are difficulties at the implementation level due to the lack of available safety information needed for hazard and risk assessments. As such, additional measures and guidance may be needed to support the nanomaterials industry and work is in progress to address these needs.

A recommendation of the definition of the term ‘nanomaterial’ (EC, 2011a) has since been adopted and is gradually being integrated into EU legislation, where appropriate. The EC recommendation defines a 'nanomaterial' as:

“A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm.

In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the number size distribution threshold of 50% may be replaced by a threshold between 1 and 50%.

By derogation from the above, fullerenes, graphene flakes and single wall carbon nanotubes with one or more external dimensions below 1 nm should be considered as nanomaterials.”

Specific provisions on nanomaterials have also been introduced into several consumer product legislations, including for biocides, cosmetics, food and food contact materials (FCMs), and modification of the annexes of the European chemicals regulation ‘REACH’ is under consideration.

Nanomaterial reporting schemes

In 2012, ten European Member States plus Croatia pushed for a European Reporting Scheme with a letter to the European Commission. Following this, the European Commission commissioned a study (RPA/BiPRO, 2015) to assess the impact of possible legislation to increase transparency on nanomaterials on the market (in terms of economic, social, and environmental factors). However, an over-arching reporting scheme for nanomaterials has not yet been realised at European-level.

However, several European countries have introduced national-level mandatory reporting schemes in order to gather available information on nanomaterials and gain an insight into levels of production, importation and distribution on the market. The first of these was launched in France during 2013, and results of the first (Ministère de l'Environnement, 2013) and second (Ministère de l'Environnement, 2015) rounds of annual reporting have since been
published. This was closely followed by a comparable scheme finalised by the Danish Environmental Protection Agency (D-EPA), which had a deadline of 30th August 2015 for the first round of registration. The Agency has since published a report (D-EPA, 2015) assessing the administrative burdens on businesses with an obligation to report to this scheme. The Belgian Council of Ministers has also set up a national nanomaterial reporting scheme, which became operational from January 2016. The key requirements of these registries are summarised in Table 3 below. A number of other European countries are considering introducing mandatory reporting schemes at the national-level, including Norway, Sweden, and Italy, but these are yet to come to fruition.

Table 3: Key requirements of nanomaterial reporting schemes in France, Belgium and Denmark

<table>
<thead>
<tr>
<th>Reporting scheme</th>
<th>Registrants</th>
<th>Main exceptions</th>
<th>Key information requirements</th>
<th>Annual reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>France - National Decree for Mandatory Reporting of Nanomaterials</td>
<td>Manufacturers or importers of nanomaterials (on their own or included in a mixture or another material) in quantities of 100g/year or above</td>
<td>The amount manufactured, imported or distributed is less than 100g/year; The substance is sold directly to consumers (general public).</td>
<td>Identity of the declarant; Identity of the nanomaterial (including physico-chemical data); Annual tonnage; Uses of the substance; Identity of the professional users.</td>
<td>1st May (from 2013 onwards)</td>
</tr>
<tr>
<td>Belgium - Royal Decree on the Placing on the Market of Substances Manufactured in the Nanoparticle Form</td>
<td>Companies that place substances and mixtures containing nanomaterials on the Belgian market in quantities of &gt;100g/year</td>
<td>The amount placed on the market is less than 100g/year; Products already subject to regulations concerning nanomaterials (e.g. biocides, foodstuffs, etc.).</td>
<td>Registrant’s identity; Characteristics of the substance; Quantity of nanomaterials placed on the market; Uses; Identity of professional purchasers and users.</td>
<td>1st January (from 2015 onwards)</td>
</tr>
<tr>
<td>Denmark - Order on the Register of Mixtures and Products Containing Nanomaterials</td>
<td>Manufacturers or importers of mixtures and articles incorporating nanomaterials that are intended for sale to the Danish general public</td>
<td>Foods and FCMs; Animal feed; Medicinal products; Medical devices; Cosmetics; Pesticides; Waste.</td>
<td>Registrant’s identity; Product information (including name, quantity; professional uses, applications); Information on nanomaterial (including REACH registration status); Chemical information on nanomaterial (including CAs/EU number and chemical formula); Optional information: Category (of preparation, process, environmental release and article); Content (% by mass) of the nanomaterial in the product/mixture; Physico-chemical information on the nanomaterial.</td>
<td>30th August (from 2015 onwards)</td>
</tr>
</tbody>
</table>
6.4 Product-specific legislation

General product safety

There is a general requirement on manufacturers to ensure a high level of product safety throughout the EU and ensure that only safe consumer products are placed on the market, laid out under the General Product Safety Directive (Council Directive 2001/95/EC) (EC, 2002). According to this Directive, producers must inform consumers of the risks associated with the products they supply, and take appropriate measures to prevent such risks. In addition to this general Directive, legislation exists for a number of specific sectors including for aeronautics, astronautics, wind energy, and automotives.

Aeronautic sector

The overarching regulation governing the aeronautic sector is Regulation (EC) No 216/2008 (the ‘Basic Regulation’) (EC, 2008d) which lays out commons rules in the field of aviation and establishes a European Aviation Safety Agency (EASA). Its central aim is to set out the main rules and principles to establish and maintain a high uniform level of civil aviation safety in Europe. This EU law applies to the design, production, maintenance and operation of aeronautical product parts and equipment, as well as to personnel and organisations involved in these activities.

The general requirements of the Basic Regulation are enforced through a number of specific Implementing Regulations, as summarised overleaf in Figure 6. Perhaps the most important of these for producers of components for aeronautic applications to be aware of are those relating to airworthiness.

In accordance with Article 5(2) of the Basic Regulation, compliance of aircraft, and of products, parts and appliances mounted thereon shall be established in accordance with the following:

a. products shall have a type-certificate. The type-certificate shall be issued when the applicant has shown that the product complies with a type-certification basis established to ensure compliance with the essential requirements detailed in Annex I of Regulation (EC) No 216/2008, and when it has no feature or characteristic making it unsafe for operation;

b. parts and appliances may be issued with specific certificates when they are shown to comply with detailed airworthiness specifications established to ensure compliance with the essential requirements detailed in Annex I of Regulation (EC) No 216/2008;

c. each aircraft shall be issued with an individual certificate of airworthiness when it is shown that it conforms with the type design approved in its type-certificate and that relevant documentation, inspections and tests demonstrate that the aircraft is in condition for safe operation;

d. organisations responsible for the maintenance of products, parts and appliances shall demonstrate their capability and means to discharge the responsibilities associated with their privileges;
e. organisations responsible for the design and manufacture of products, parts and appliances shall demonstrate their capability and means to discharge the responsibilities associated with their privileges.

In addition, Article 6(1) of the Basic Regulation states that products, parts and appliances must comply with the environmental protection requirements contained in Amendment 8 of Volume I and in Amendment 5 of Volume II of Annex 16 to the Chicago Convention on International Civil Aviation (ICAO, 2006).

In relation to this, Commission Regulation (EU) No 748/2012 (EC, 2012a) lays down common technical requirements and administrative procedures for the airworthiness and environmental certification of products, parts and appliances specifying the:

a. issue of type-certificates, restricted type-certificates, supplemental type-certificates and changes to those certificates;

b. issue of certificates of airworthiness, restricted certificates of airworthiness, permits to fly and authorised release certificates;

c. issue of repair design approvals;

d. showing of compliance with environmental protection requirements;

e. issue of noise certificates;

f. identification of products, parts and appliances;

g. certification of certain parts and appliances;

h. certification of design and production organisations;

i. issue of airworthiness directives.

The European Aviation Safety Agency (EASA) has been established to assist the Commission by preparing measures to be taken for the implementation of Regulation (EC) No 216/2008 and its implementing regulations. This includes developing a) certification specifications, including airworthiness codes and acceptable means of compliance; and b) guidance material to be used in the certification process. Further information and guidance can be found on the EASA website (https://www.easa.europa.eu/).

In their Work Programme 2016, EASA (2015) acknowledges that assuring the right level of in-house expertise on innovative technologies (e.g. nanotechnologies, composite materials) is one of the main operational challenges in relation to their defined actions portfolio. However, to the best of our knowledge, there are no specific regulatory requirements regarding the use of nanomaterials or nanocomposites in aircraft products, parts and appliances at present.
Each Part to each implementing regulation has its own Acceptable Means of Compliance and Guidance Material (AMC/GM). These AMC/GM are amended along with the amendments of the regulations. These AMC/GM are so-called 'wilf' (non-binding rules), and put down in form of EASA Decisions. A comprehensive explanation on AMC in form of questions and answers can be found on the FAQ section of the EASA website.

Furthermore, Certification Specifications are also related to the implementing regulations, respectively their parts. Like AMC/GM they are put down as Decisions and are non-binding.
**Astronautic sector**

The governance of space activities in Europe is based on cooperation between the EU, the European Space Agency (ESA), and their member countries. Ensuring effective and efficient cooperation and coordination between these actors is considered essential to optimise the impacts of European policies and investments in space.

The Treaty of Lisbon established a firm legal basis for the space policy of the European Union. In a key policy document, the EC (2011c) identified four key objectives for the EU’s space strategy:

- promote technological and scientific progress;
- foster innovation and industrial competitiveness;
- ensure that European citizens fully benefit from European space applications;
- strengthen Europe’s role in space at an international level.

Following this, the EC (2013a) published a Communication establishing the basis for an EU Space Industrial Policy, centred on five specific objectives:

1. Establish a coherent and stable regulatory framework;
2. Further develop a competitive, solid, efficient and balanced industrial base in Europe and support SME participation;
3. Support the global competitiveness of the EU space industry by encouraging the sector to become more cost-efficient along the value chain;
4. Develop markets for space applications and services;
5. Ensure technological non-dependence and an independent access to space.

As part of this, it was highlighted that as space activities expand, the appropriateness of the existing regulatory framework needs to be examined to ensure the security, safety and sustainability of such activities and their economic development.

In relation to safety specifically, to date the focus in Europe has been on developing standards, with both ESA and CEN publishing standards related directly to product assurance, engineering, and safety of space systems. A comprehensive overview of available standards has been published relatively recently by Pelton and Jakhu (2011). To the best of our knowledge, there are no specific regulatory requirements regarding the use of nanomaterials or nanocomposites in products, parts and appliances for space systems at present.

**Automotive sector**

New motor vehicles and their component parts must meet the same technical requirements throughout the European Union with a view to ensuring a high level of road safety and environmental protection. The main legislation relating to the general safety of motor vehicles, their systems, components and technical units is Regulation (EC) No. 661/2009 (EC, 2009c), which sets out technical requirements and procedures to ensure that new motor vehicles meet EU safety and energy efficiency standards. Specifically, this regulation...
establishes requirements for the type-approval of: the safety of motor vehicles and their trailers; the energy efficiency of motor vehicles (by making it mandatory to install tyre pressure monitoring systems and gear shift indicators), and; the safety and energy efficiency of tyres and their levels of noise emissions. Manufacturers must guarantee that new vehicles sold, registered or put into service in the EU are type-approved in accordance with this regulation.

In relation to new technologies, the European Commission plans to monitor technical developments in enhanced passive safety requirements and consider possible inclusion of new safety features and enhanced active safety technologies. The Commission will report on the latest developments to the European Parliament and the Council in an envisaged Communication. The Communication will be based on a report published in March 2015 (EC, 2015) which assessed the benefit and feasibility of a range of new technologies and unregulated measures in the field of vehicle occupant safety and protection of vulnerable road users. No specific mention of nanotechnologies is made within this report.

Further information on safety in the automotive sector is available on the EC website (http://ec.europa.eu/growth/sectors/automotive/safety/).

Wind energy sector

The Renewable Energy Directive (2009/28/EC) (EC, 2009b) establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020, to be achieved through the attainment of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020. Progress towards national targets is measured every two years when EU countries publish national renewable energy progress reports. Energy from renewable sources means energy from non-fossil sources, such as wind, solar, geothermal, hydropower, biomass and sewage treatment plant gas (e.g. methane).

If the wind energy sector grows as planned, it will have a major impact on the working environment. At the moment, Europe is the leading global supplier of wind turbines and has the largest working wind energy capacity. With an increasing number of workers now employed in various aspects of the wind energy sector, occupational safety and health considerations are a primary concern. As highlighted by the European Agency for Safety and Health at Work (EU-OSHA, 2013), many aspects of siting, erecting, maintaining, servicing and possibly dismantling wind turbines are unique, and even if most of the job hazards that these workers will face are not, the working environments and combinations in which they are found create unique challenges. New technologies (such as nanotechnologies) or working processes associated with wind energy will also lead to new hazards, which call for new combinations of skills to deal with them. A recent review published by EU-OSHA (2013) considers the occupational safety and health issues in the wind energy sector, both onshore and offshore, within the EU Member States covering the activities associated with wind energy — from the design and manufacturing of wind turbine parts, through the transport, installation and maintenance, to emergency rescue and waste treatment. It is acknowledged
the occupational safety and health implications of new designs and technologies have to be carefully considered before they are used, and that the use of nanomaterials raises potential issues for workers involved in manufacturing and at any other stage where repairs or decommissioning work might result in exposure.

The promotion of best practice and harmonisation of occupational safety and health regulation, standards, training, safety rules, documentation of work, etc. is seen as vital to reducing risks to workers involved in the wind industry (EU-OSHA, 2013), and a number of international associations are actively working towards this such as the European Wind Energy Association (EWEA). EWEA (2013) have recently published guidelines on working with the wind safely, but these focus on onshore and offshore facilities and don’t cover the manufacturing and production stage of wind turbines.

A number of international standards for wind turbines have been published in the IEC 61400 series, principally covering design requirements and certification. One important legislative development in the wind energy industry is the planned update to the European wind turbine standard EN 50308 (Wind turbines — safety requirements for design, operation and maintenance) (BSI, 2004). This revision is still on-going but it will make the need to perform risk assessments more explicit (EU-OSHA, 2013), amongst other aspects.

6.4 End-of-life legislation

General waste framework

Numerous end-of-life and environmental regulations exist in Europe, addressing a range of issues such as air, water, waste and industrial emissions. In 2011, a review of environmental legislation for the regulatory control of nanomaterials was published at the request of the European Commission to inform regulatory decision-making (Mileau/AMEC, 2011). This review showed that all environmental legislation could be considered to address nanomaterials in principle, but may pose specific challenges, principally due to lack of relevant data.

A general framework for waste policies has been established under Directive 2008/98/EC (EC, 2008c), which includes the definition of concepts such as waste, recovery and disposal and key requirements for waste management. This follows a waste management hierarchy which recommends prevention of waste as the preferred option, followed by re-use, recycling and recovery. Final disposal should be considered as a last resort.

Currently, wastes containing nanomaterials are treated as any other waste under the Waste Framework Directive without any specific requirements. There is no definition of waste containing nanomaterials and therefore no measures specifically designed to deal with the possible risks associated with nanomaterials in wastes. The main challenges in relation to the coverage of nanomaterials under this Directive, as noted by the 2011 review, include uncertainties surrounding the classification of specific nanomaterials as hazardous under the CLP Regulation and the disposal of consumer products containing nanomaterials in municipal waste streams.
Related to this, the List of Wastes (EC, 2000) provides a common encoding of waste characteristics, including the classification of hazardous wastes. Carbon black is included in the current list, as a waste from inorganic chemical processes. No other nanomaterial types are listed at present.

**Aeronautic sector**

The handling of end-of-life aircraft is a relatively young topic and relatively little knowledge about the aircraft end-of-life process is available. However, the recycling of aircraft materials has come into greater focus in recent years, mainly due to the increase in the number of aircraft reaching the end-of-life stage (Ribeiro and Gomes, 2015).

As highlighted by the Environment Agency (EA, 2014), decommissioned aircraft tend not to become waste immediately, but are typically placed into storage under a care and maintenance programme pending a decision about what to do with them. They can remain in this state for a long period and during this time may have parts removed to support the operator’s remaining fleet or for resale, before either being brought back into service or ultimately being scrapped. When the decision has been made that an aircraft will be scrapped they are then considered as waste, but the process they go through initially is often indistinguishable from that for aircraft in storage with the aircraft continuing to undergo care and maintenance while the parting out takes place to ensure the airworthiness of the parts being removed. When all parts required by the owner have been removed, the remainder of the airframe is broken up and the materials recycled or, where necessary, disposed of.

Currently there is no legislation in Europe which specifically regulates the handling of end-of-life aircraft, to the best of our knowledge. However, the continuing airworthiness of aircraft and aeronautical products, parts and appliances is subject to regulation under Commission Regulation (EU) No. 1321/2104 which lays out common technical requirements and administrative procedures. In particular, organisations and personnel involved in the continuing airworthiness of aircraft and components, including maintenance, shall comply with the provisions of Annex I (Part-M).

The trend in terms of legislation in the transportation sector has been towards Extended Producer Responsibility (EPR), and it has been suggested that the aviation industry could in the future face legislation similar to organisations in the automotive industry (Ribeiro and Gomes, 2015). Some of the largest aircraft manufacturers have started to develop alternative approaches for how to handle aircraft at the end-of-life stage, with Airbus launching the PAMELA project (Process for Advanced Management of End-of-Life Aircraft), and Boeing founding the industry association AFRA (Aircraft Fleet Recycling Association). It remains to be seen what approach and requirements will be adopted in a regulatory level in the EU going forward.

**Astronautic sector**

Similarly to the aeronautic sector, relatively little knowledge about the end-of-life process for space systems and their component parts is available. Discussions to date have largely
focused on requirements for space debris mitigation. In order to remove mass from densely populated orbits, the European Space Agency (ESA, 2005) recommend that spacecraft and orbital stages be commanded to re-enter the Earth’s atmosphere within 25 years of mission completion, if their deployment orbit altitude is below 2000 km (i.e. in the Low-Earth Orbit [LEO] region). Alternatively, they may be re-orbited above 2000 km. For spacecraft and orbital stages in or near the geostationary ring, re-orbiting after mission completion to a 'graveyard orbit' is considered to be the only viable option. The recommended re-orbit altitude is about 300 km above the geosynchronous Earth orbit (GEO) ring. This guarantees that the re-orbited object will never interfere with operational GEO spacecraft.

Currently there is no legislation in Europe which specifically regulates the handling of end-of-life space systems, to the best of our knowledge. Following decommissioning and return to Earth, is it likely that space systems will undergo long-term storage and gradual ‘parting-out’, as per the aeronautic sector.

**Automotive sector**

The main legislation relating to the waste management of vehicles is the End-of-life Vehicles (ELV) Directive (2000/53/EC, as amended) (EC, 2013b) which aims at making dismantling and recycling of ELVs more environmentally friendly. It sets clear quantified targets for reuse, recycling and recovery of the ELVs and their components. It also pushes producers to manufacture new vehicles without hazardous substances (in particular lead, mercury, cadmium and hexavalent chromium), thus promoting the reuse, recyclability and recovery of waste vehicles. The remaining specific exemptions to the prohibition of the use of hazardous substances in vehicles are listed in Annex II to the ELV Directive and are subject to regular reviews according to technical and scientific progress.

Related to this is Directive 2005/64/EC on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability (EC, 2005). This Directive lays down administrative and technical rules to ensure that a vehicle’s parts and materials may ultimately be reused, recycled and recovered as much as possible. It also ensures that the reused components do not cause any safety or environmental risks.

**Wind energy sector**

The recent expansion of the wind energy sector is creating a growing waste disposal issue associated with the future decommissioning of wind turbines, with composite wind turbine blades in particular presenting a challenge for waste management (Cherrington et al., 2012, Ortegon et al., 2013). There is currently little legislation present for the regulation of end-of-life waste management for the wind energy industry in Europe. However, general European waste management policy effectively diverts waste from landfill and drives towards energy recovery.

The introduction of current waste legislation in the automotive industry has brought forward important lessons that can be utilised in industries that share similar issues of disposal for composite materials. If legislation is introduced within the wind energy industry it has been
suggested that it will likely be similar to end-of-life vehicles legislation which encompasses Extended Producer Responsibility (EPR) by introducing set recycling and recovery targets for manufacturers (Cherrington et al., 2012). Cherrington et al. (2012) propose that wind turbine manufacturers should adopt a proactive approach to responsible waste management as investigating solutions now will provide time to develop efficient systems and drive down technology costs; therefore reducing the economic penalties from legislation.

7. Initial Safety Survey of EIROS Partners

In order to inform the evaluation of nanosafety to be undertaken in later tasks of the project, a questionnaire was developed and used to gather some initial information about current working practices across all partners involved in the EIROS project.

7.1 Scope & methodology

Information was collected through a short online questionnaire using the SurveyMonkey® platform, which was distributed to the 17 project partners undertaking technical work involving the handling and use of nanomaterials (NM), NM-polymer resins, and/or NM-composite structures in the EIROS project. The questionnaire requested information on:

- Company identity;
- In-house safety training and documents;
- Workplace exposure assessment; and
- Material handling, storage and disposal.

Appropriate instructions for completion were provided where necessary. To encourage response, the questionnaire was designed to be completed within 10 minutes, with extensive use of drop down menus or ‘tick boxes’ and free text responses being restricted to a minimum. A copy of the final questionnaire is provided in Appendix 1.

7.2 Summary of survey responses

Number of responses

A total of 20 questionnaire responses were returned from the project partners undertaking technical work involving the handling and use of NM, NM-polymer resins, and/or NM-composite structures in the EIROS project (with 3 partner organisations submitting multiple responses from different workers). It should be noted that not all of the respondents answered all of the questions (for example, respondents may have provided information on in-house safety training, but not on material handling).

The small scale of the anonymised survey precludes quantitative analysis and the information has been analysed qualitatively, rather than undertaking a comparison of practices between...
partners and activities or a statistical analysis of the small and bespoke nature of the responses.

**In-house safety training and documents**

*Experience with nanomaterials*

The majority of respondents (15; 75%) indicated that they have prior experience working with nanomaterials, with nearly half of these having over 5 years’ experience. The remaining respondents (5; 25%) indicated that they don’t currently work with nanomaterials. These respondents were typically from the end-user organisations that will utilise the NM-composites developed as part of the EIROS project in their components/products.

**In-house safety training**

Figure 7 below provides a summary of responses relating to in-house safety training.

![Figure 7: Overview of responses regarding in-house safety training](image)

It can be seen that, with the exception of a single respondent, the majority of respondents (19; 95%) indicated that they have received some form of workplace and laboratory safety training, typically within the last 12-18 month period. Generally a combination of training types has been provided including verbal briefings, guidance documents, and, to a lesser extent, practical demonstrations, SOPs/risk assessments, and journal papers.
The number of respondents who have received specific training on nanomaterial hazards was slightly lower (14; 70%), with 6 respondents (30%) indicating they haven’t received any in-house training on nanomaterial hazards. Current best practice guidance recommends that workers should be trained and educated on the hazards of working with nanomaterials and the precautions that should be taken to avoid or minimise exposure, including the proper selection of PPE. However, it should be noted that the survey respondents that indicated that they haven’t received any in-house training on nanomaterial hazards are from the end-user partner organisations that will use nanomaterials within their products for the first time as part of the EIROS project and, as such, are looking to develop and implement safe working practices throughout the course of the project. Where training has been received on nanomaterial hazards, it has typically been through reviewing guidance documents, SOPs/risk assessments, and the primary scientific literature, with the provision of formal verbal briefings and practical demonstrations being less common.

**In-house documentation**

Figure 8 below summarises the availability of in-house safety documents across the partner organisations.

**Figure 8: Overview of responses regarding in-house safety documentation**

The majority of respondents (18; 90%) indicated that they are aware of their organisation having instructions or guidance notes on chemical safety, with a slightly lower number indicating that they are aware of their organisation having risk assessments (12; 63%) and maintenance records for local exhaust ventilation and other control measures (12; 63%). Similarly to the training aspects, the availability of documentation relating specifically to
nanomaterials was less common, with a lower number of respondents indicating that they are aware of their organisation having instructions or guidance notes for how to work specifically with nanomaterials (6; 32%), written procedures for dealing with accidental release and spillages of nanomaterials (3; 16%), or written procedures for dealing with waste containing nanomaterials (5; 26%). It was noted by one respondent that they use safety data sheets (SDS) as the primary source of information for informing safe use of (nano)materials in the workplace.

A small number of respondents (≤ 4; ≤ 20%) indicated that their in-house documentation could be made available to the IOM for review.

**Workplace exposure assessment**

As summarised below in Figure 9, there was a limited indication of previous exposure measurements having been carried out in some of the partner organisations, with air monitoring (9; 45%) being the most frequent, followed to a lesser extent by personal monitoring (4; 21%) and surface sampling (2; 11%).

![Figure 9: Overview of responses regarding previous exposure measurements](image)

A small number of respondents (2; 10%) indicated that the documents from previous exposure measurements could be made available to the IOM for review.

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Material handling, storage and disposal

Packaging and labelling

Table 4 below provides a summary of how materials are packaged and labelled across the partner organisations.

Table 4: Summary of responses regarding how materials are packaged and labelled

<table>
<thead>
<tr>
<th>Nanomaterials (NM)</th>
<th>Primary (inner) container</th>
<th>Secondary (outer) container</th>
<th>Pack type size</th>
<th>Labelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single, tied plastic bag (1)</td>
<td>Cardboard box (3)</td>
<td>&lt; 500g (6)</td>
<td>Hazard label attached (7)</td>
<td></td>
</tr>
<tr>
<td>Double, tied plastic bag (1)</td>
<td>Plastic bag (3)</td>
<td>500g – 1kg (2)</td>
<td>No hazard labels (3)</td>
<td></td>
</tr>
<tr>
<td>Paper sack (2)</td>
<td>Sealed rigid container (2)</td>
<td>1 – 5kg (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sealed rigid container (5)</td>
<td>None (5)</td>
<td>&gt;10kg (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| NM-Polymer Dispersion                   | Single, tied plastic bag (1)              | Cardboard box (3)                          | < 500g (3)     | Hazard label attached (8) |
|                                        | Sealed rigid container (8)                | Plastic bag (1)                            | 500g – 1kg (4) | No hazard labels (3)     |
|                                        | None (5)                                   | Sealed rigid container (3)                 | 1 – 5kg (3)   |                            |
|                                        |                                            | None (6)                                   | 5 – 10kg (1)  |                            |

| NM-Composite Structures                 | Double, tied plastic bag (1)              | Cardboard box (1)                          | < 500g (2)     | Hazard label attached (3) |
|                                        | Paper sack (2)                             | Plastic bag (2)                            | 500g – 1kg (3) | No hazard labels (6)     |
|                                        | Sealed rigid container (1)                | Sealed rigid container (2)                 | 1 – 5kg (2)   |                            |
|                                        | None (10)                                  | None (9)                                   |                |                            |

Raw nanomaterials are typically packed in small quantities (< 500g), although it was noted that four respondents handle larger pack sizes, over 10 kg in a single instance. The nanomaterials are most frequently packed in sealed rigid containers inside either a secondary plastic bag or cardboard box, in accordance with best practice guidance. However, the use of ‘soft’ packaging was reported in three instances, either a double tied plastic bag or paper sack inside a cardboard box or a single tied plastic bag with no secondary containment.

In the case of NM-polymer dispersions, pack sizes typically range from < 500g up to 5kg, with a single respondent indicating that they handle larger pack sizes of up to 10 kg. The NM-polymer dispersions are most frequently packed in sealed rigid containers with no outer containment, although secondary containment in a cardboard box was reported in three instances. The use of ‘soft’ packaging was reported by one respondent, with the dispersions being stored in a single-tied plastic bag inside a secondary plastic bag.

For dispersible nanomaterials, whether suspended in liquids or dry particle form, current best practice guidance recommends that secondary containment (e.g. double bagging or bottles inside robust plastic outer containers) capable of withstanding foreseeable impacts should be used.

According to the survey responses, NM-composite structures are typically not packaged. Where they are packaged, pack sizes range from < 500g up to 5kg and a range of containment types may be used varying from sealed rigid containers to plastic bags/paper sacks inside either a cardboard box or plastic bag.
The majority of respondents indicated that hazard labels are typically attached to the packaging of raw nanomaterials and NM-polymer dispersions, in accordance with best practice guidance. NM-composite structures, which are often unpackaged, tend not to have hazard labels. In relation to this, one respondent commented that there is often no specification provided of the presence of nanomaterials in the range of products they work with.

Storage

Table 5 below provides a summary of how materials are stored across the partner organisations.

Table 5: Summary of responses regarding how materials are stored

<table>
<thead>
<tr>
<th>Storage containment</th>
<th>Storage location</th>
<th>Storage ventilation</th>
<th>Storage access</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nanomaterials (NM)</strong></td>
<td>In designated cabinet (3)</td>
<td>With ventilation (5)</td>
<td>With access restricted (2)</td>
</tr>
<tr>
<td>Transferred to new container (2)</td>
<td>In cabinet for general chemicals (6)</td>
<td>With no ventilation (5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>On open access shelves/storage (2)</td>
<td></td>
<td>Black</td>
</tr>
<tr>
<td></td>
<td>In original packaging (9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>In designated cabinet (3)</td>
<td>With ventilation (5)</td>
<td>With no access restrictions (7)</td>
</tr>
<tr>
<td></td>
<td>In cabinet for general chemicals (6)</td>
<td>With no ventilation (5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>On open access shelves/storage (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NM-Polymer Dispersion</strong></td>
<td>In designated cabinet (3)</td>
<td>With ventilation (6)</td>
<td>With access restricted (4)</td>
</tr>
<tr>
<td>Transferred to new container (4)</td>
<td>In cabinet for general chemicals (7)</td>
<td>With no ventilation (4)</td>
<td>With no access restrictions (5)</td>
</tr>
<tr>
<td></td>
<td>On open access shelves/storage (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In original packaging (7)</td>
<td>In designated cabinet (3)</td>
<td>With ventilation (6)</td>
<td>With access restricted (4)</td>
</tr>
<tr>
<td>Transferred to new container (4)</td>
<td>In cabinet for general chemicals (7)</td>
<td>With no ventilation (4)</td>
<td>With no access restrictions (5)</td>
</tr>
<tr>
<td></td>
<td>On open access shelves/storage (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NM-Composite Structures</strong></td>
<td>In designated cabinet (1)</td>
<td>With ventilation (3)</td>
<td>With access restricted (2)</td>
</tr>
<tr>
<td>Transferred to new container (4)</td>
<td>In cabinet for general chemicals (2)</td>
<td>With no ventilation (6)</td>
<td>With no access restrictions (6)</td>
</tr>
<tr>
<td></td>
<td>On open access shelves/storage (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In original packaging (5)</td>
<td>In designated cabinet (1)</td>
<td>With ventilation (3)</td>
<td>With access restricted (2)</td>
</tr>
<tr>
<td>Transferred to new container (4)</td>
<td>In cabinet for general chemicals (2)</td>
<td>With no ventilation (6)</td>
<td>With no access restrictions (6)</td>
</tr>
<tr>
<td></td>
<td>On open access shelves/storage (6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Raw nanomaterials and NM-polymer dispersions are typically stored in their original packaging. Only three respondents indicated that they store nanomaterials and/or NM-polymer dispersions in a designated cabinet, with the majority of respondents indicating that they store these materials in a cabinet for general chemicals with no access restrictions. A couple of respondents indicated that they store nanomaterials and/or NM-polymer dispersions on open-access shelves/benches/storage. The use of ventilation varies, with approximately half of respondents indicating that nanomaterials and/or NM-polymer dispersions are stored with ventilation in place. One respondent highlighted that NM powders are stored in accordance with safety data sheet (SDS) requirements, and another highlighted that the nature of storage depends on the quantity of the material. Material-specific requirements (e.g. sensitivity to light or moisture) also need to be taken into account.

NM-composite structures may be stored in their original packaging or transferred to a new container. The majority of respondents indicated that NM-composite structures are stored on open-access shelves/benches/storage with no restrictions or ventilation in place.
**Safety Data Sheets**

Where respondents work with nanomaterials (NM), NM-polymer dispersions and/or NM-composite structures, the majority indicated that they request a safety data sheet (SDS) for the materials that they receive from external sources. A single respondent indicated that they do not request a SDS for NM-composite structures, but this organisation primarily works with NMs and NM-polymer dispersions rather than composite materials.

Where organisations supply materials, the majority indicated that they would provide a SDS for nanomaterials and/or NM-polymer resins. NM-composite structures, on the other hand, are frequently provided without a SDS.

It is important that SDS for nanomaterials and nano-enabled products are informative and reflect as best as possible current knowledge in the field, and do not simply rely on information on bulk (non-nanoscale) materials which may have the same chemical composition but different hazard profiles.

**Personal protective equipment**

Figure 10 below provides a summary of the use of Personal Protective Equipment (PPE) across the partner organisations.

![Figure 10: Overview of responses regarding use of PPE](image-url)
Of the 18 respondents that answered the question regarding PPE usage, it can be seen that the majority wear disposable gloves (14; 78%), safety glasses (14; 78%), and/or overalls/lab coats (11; 61%). In accordance with best practice guidance, it is recommended that:

- Protective clothing should ideally be made from air-tight fabrics made of non-woven textiles; cotton, wool or knitted materials are not recommended;
- If clothing is re-usable, regular laundering is advised to prevent secondary exposure;
- Closed toe shoes, made of a low permeability material, are recommended to be worn, along with disposable, over-the-shoe booties to prevent tracking of nanomaterials out of the work area;
- Two layers of single-use, disposable neoprene or nitrile gloves are recommended and these should fit the wearer correctly and cover the wrists;
- Gloves should be inspected for visual wear and tear and changed regularly, and special attention should be given to the proper removal and disposal of gloves to prevent skin contamination;
- Suitable eye protection should be worn; as a minimum, close-fitting safety glasses are advised.

The majority of respondents also indicated that they wear some form of respiratory protective equipment, either a face-fitting respirator (10; 56%) or a disposable facemask (7; 39%), including the partners most likely to be handling nanomaterial powders during the project. However, only three respondents indicated that they had been face-fit tested. Where RPE is required, current best practice guidance recommends that appropriate steps should be taken to minimise worker exposure through the development of a complete respiratory protection program, including:

- the type of respirator should be chosen to reflect the nature of the hazard;
- a medical evaluation is often used to determine the employee’s ability to use a respirator;
- face-fit testing is strongly recommended to ensure effectiveness of RPE on an individual basis;
- respirator training is recommended for all staff using respirators. It should be comprehensive, understandable and recurring.

Two respondents indicated that they do not use any PPE in the work area, however neither of these will be handling nanomaterial powders or dispersions in the project. Where PPE is used, it is typically removed before leaving the work area (15; 83%) in accordance with best practice guidance.

**Cleaning and maintenance**

As summarised in Figure 11 below, of the 18 respondents that answered the question regarding workplace cleaning the majority indicated that the work area is cleaned regularly, either after the task is completed (7; 39%), daily (2; 11%), or weekly (2; 11%) depending on the nature of the work, in accordance with best practice guidance. Three respondents (17%) indicated that the work area is not cleaned regularly, two of which will likely work with
nanomaterials in either powder or dispersion form as part of the project. One of the respondents cited resource pressure as the limiting factor in enabling regular workplace cleaning.

![Is the work area cleaned regularly?](image)

**Figure 11: Overview of responses regarding cleaning of the work area**

Where ventilation and exposure control measures are in place, the majority of respondents (14; 82%) indicated that these are regularly checked and maintained, in accordance with best practice guidance.

**Waste disposal**

Of the 12 respondents that answered the question regarding waste disposal, the majority indicated that nanomaterials (11; 92%), NM-polymer resins (9; 75%), and NM-composite structures (8; 73%) are disposed of as hazardous waste, in accordance with best practice guidance. It should be noted that any materials or equipment that has come into contact with nanomaterials, and all debris resulting from the clean-up of a spillage or accidental release, should also be considered as nanomaterial-containing waste and disposed of accordingly.

**7.3 Conclusion**

Preliminary consideration of the responses to this small-scale survey indicates that, in general, the majority of partners have reasonable working practices in place for the types of tasks and materials they will likely be involved with as part of the EIROS project, with the exception of a few key areas such as worker training, exposure monitoring, and face-fit testing of RPE. However, a much more thorough assessment of control measures will be undertaken as part of the workplace exposure monitoring visits and bespoke guidance provided as part of the evaluation of nanosafety to be undertaken in later tasks of the project. In the meantime, all partners are referred to Sections 4 and 5 of this deliverable for general best practice guidance on risk management and the safe handling and use of nanomaterials.
8. References

BAUA 2015. Safe handling of nanomaterials and other advanced materials at workplaces. Federal Institute for Occupational Safety and Health (BAuA).


HSE 2013b. Using nanomaterials at work - including carbon nanotubes (CNTs) and other biopersistent high aspect ratio nanomaterials (HARNs). Health and Safety Executive.

HSE 2014. REACH and articles. Health and Safety Executive.


NANOSAFE 2008. Guidelines for safe handling, use and disposal of nanoparticles.


Appendix 1: Survey Monkey Questionnaire

EIROS Safety Questionnaire

1. Introduction

Dear Colleague,

IOM leads a series of tasks in the EIROS project focused on supporting safety of nanomaterials, processes and components.

We would like to gather some initial information about your current practices working with nanomaterials and related substances in the project and have constructed this questionnaire to help us do so.

The questionnaire should be completed by at least one representative from each partner organisation carrying out experimental work or handling materials used or produced in the EIROS project.

We hope that the questionnaire is self-explanatory and you find it straightforward to complete, but are happy to provide any assistance you may need to answer a question, so please do not hesitate to contact us about it.

In accordance with UK Data Protection legislation, the information you provide will be:

1. stored securely;
2. only used for the EIROS project;
3. used in a report aggregated to the institutional level, so that no individuals are identified.

Only anonymised data will be retained after the end of the project for any future use by EIROS partners.

Many thanks for your cooperation,

Sheona Read & Gordon Fern

On behalf of the IOM team for EIROS

Sheona Read, tel. +44 131 449 8043 / Sheona.Read@iom-world.org
Gordon Fern, tel. +44 131 449 8072 / Gordon.Fern@iom-world.org

This project has received funding from the European Union’s Horizon 2020 Research and innovation programme under grant agreement N° 685842
EIROS Safety Questionnaire

2. Your identity

1. Please select your Partner organisation

2. What is your name?

3. What is your email address?
## 3. In-house Safety Training & Documents

### 1. What training have you received about potential safety hazards?

<table>
<thead>
<tr>
<th>Workplace safety</th>
<th>Verbal briefing</th>
<th>Practical demonstration</th>
<th>Guidance documents</th>
<th>SOPs/Risk Assessments</th>
<th>Journal papers</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nanomaterial hazards</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2. Please indicate when this training last took place:

<table>
<thead>
<tr>
<th>Verbally briefing</th>
<th>2016</th>
<th>2015</th>
<th>2014</th>
<th>before 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical demonstration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reviewing SOPs / Risk Assessments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking at relevant guidance / websites</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reviewing scientific literature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3. How many years have you been working with nanomaterials?

- [ ] < 1 year
- [ ] 1-2 years
- [ ] 3-5 years
- [ ] > 5 years
- [ ] I don’t work with nanomaterials
4. Do you know if your organisation has any of the following documents and, if so, can they be made available to the IOM for review?

<table>
<thead>
<tr>
<th>Documents available to IOM?</th>
<th>Yes/no</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Instructions or guidance notes on chemical safety</td>
<td></td>
</tr>
<tr>
<td>2. Instructions or guidance notes for how to work specifically with nanomaterials</td>
<td></td>
</tr>
<tr>
<td>3. Risk assessments</td>
<td></td>
</tr>
<tr>
<td>4. Written procedure for dealing with accidental release and spillages of nanomaterials</td>
<td></td>
</tr>
<tr>
<td>5. Written procedure for dealing with wastes that contain nanomaterials</td>
<td></td>
</tr>
<tr>
<td>6. Maintenance records for the local exhaust ventilation systems and other control measures</td>
<td></td>
</tr>
<tr>
<td>Other documents not mentioned above (please specify)</td>
<td></td>
</tr>
</tbody>
</table>

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EIROS Safety Questionnaire

4. Workplace Exposure Assessment

1. Have any previous exposure measurements been carried out in your workplace and, if so, can the documents be made available to IOM for review?

<table>
<thead>
<tr>
<th>Documents available to IOM?</th>
<th>Available?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air monitoring (e.g. using instruments or sampling pumps)</td>
<td></td>
</tr>
<tr>
<td>Personal monitoring (e.g. using a sampling pump worn by individuals)</td>
<td></td>
</tr>
<tr>
<td>Surface sampling (e.g. wipe samples taken from the benches)</td>
<td></td>
</tr>
</tbody>
</table>

This project has received funding from the European Union’s Horizon 2020 Research and innovation programme under grant agreement N° 685842
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4. Do you provide a Safety Data Sheet (SDS) for the materials that you supply?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Don't know</th>
<th>I don't supply this material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanomaterials (NM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NM-Polymer resins</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NM-Composite structures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other (please specify): 

5. Are ventilation and exposure control measures in the work area regularly checked and maintained?

- [ ] Yes
- [ ] No
- [ ] I don't know

Other (please specify):

6. Is the work area cleaned regularly?

- [ ] No
- [ ] Yes, after task is completed
- [ ] Yes, daily
- [ ] Yes, weekly
- [ ] Yes, monthly
- [ ] Yes, don't know the frequency
- [ ] Don't know

Other (please specify):
7. What personal protection equipment (PPE) do you use in the work area?
   - None
   - Overalls/lab coat
   - Tyvek suit
   - Disposable gloves
   - Reusable gloves
   - Safety glasses
   - Visor
   - Disposable facemask
   - Face-fitting respirator
   Other (please specify):

8. If a respirator is worn, have you been face-fit tested?
   - Yes, annually
   - Yes, every 2 years
   - Yes, every 3 years
   - No
   Other (please specify)

9. Is personal protective equipment (e.g. gloves, labcoat/overalls) removed before leaving the work area?
   - Yes
   - No
   Other (please specify)

10. How are waste materials disposed of?

<table>
<thead>
<tr>
<th></th>
<th>Hazardous waste</th>
<th>General waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanomaterials (NM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NM - Polymer resins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NM - Composite structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
If you wish to provide any other information which may be relevant, please provide details below or email sheona.read@iom-world.org

1. Additional information: