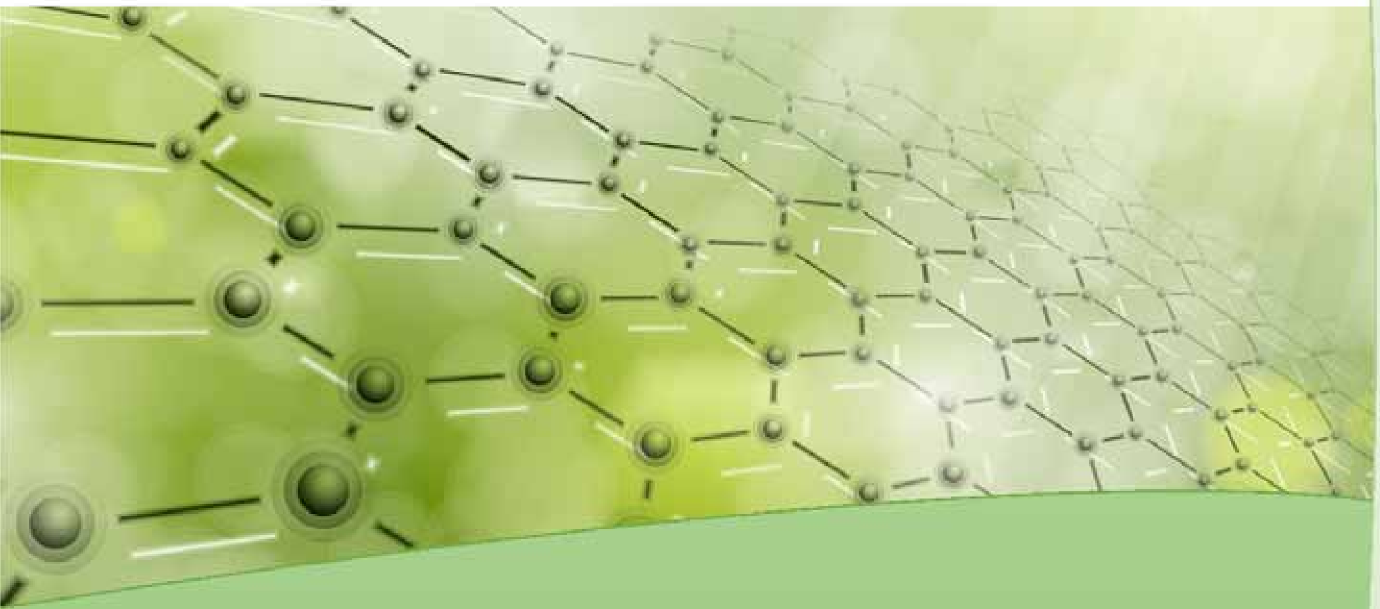
NANO SAFE PACK

Mini-Guide



Best practice for the safe handling and use of **nanoparticles** in **packaging** industries

Mini-Guide: Best practice for the safe handling and use of nanoparticles in packaging industries

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Contents

1. Introduction

Nanotechnology is one of the fastest growing and most promising technologies in our society, promoting the development of a new generation of smart, innovative products and processes that have created tremendous growth potential for a large number of industrial sectors.

In the specific case of the packaging industry, the application of nanotechnology is mainly associated with the incorporation and dispersion of additives at the nanometre scale (commonly called 'nanofillers') into the polymer matrix, including thermoplastic polymers, thermosets, and promising new renewable raw materials. The use of these nanofillers opens new business opportunities to the industry, principally derived from the manufacture of nanocomposites - polymers reinforced with particles that have one or more dimensions of the order of 100 nanometers (nm) or less, enabling the development of new materials with oxygen barrier properties, heat resistance, improved dimensional stability or mechanical performance.

Along with the foreseen benefits, there is an on-going debate about the potential effects of nanomaterials and nano-enabled products on human health and the environment. A few observations regarding some potentially harmful effects of engineered nanoparticles have, in some cases, overshadowed the dramatic benefits of these materials and their nanotechnology-enabled applications, highlighting the need for a safe and responsible approach to the development of nanocomposites and nano-enabled packaging applications.

In this context, the NanoSafePack project has developed a Best Practice Guide to support the safe handling and use of nanomaterials in packaging industries, considering integrated strategies to control the exposure to nanoparticles in industrial settings, and provide the SMEs with scientific data to minimise and control the nanoparticles release and migration from the polymer nanocomposites placed on the market.

The development of the Best Practice Guide was informed by research activities undertaken as part of the project, which included a complete hazard and exposure assessment to obtain new scientific data about the safety of polymer composites reinforced using nanometer-sized particles, an evaluation of the effectiveness of risk management measures, and a life cycle assessment of nanocomposites to evaluate impacts during manufacture, use and disposal.

The purpose of this mini-guide, which has been developed to accompany the full version of the Best Practice Guide, is to provide an overview of:

- the main benefits of nanotechnology in the packaging industry;
- the structure and contents of the full version of the Best Practice Guide;
- recommendations for the safe handling and use of nanofillers, demonstrated using a number of case studies.

At the end of this document, further information is provided on how to obtain the full version of the Best Practice Guide.

2. Main benefits of nanotechnology in the packaging industry

The use of nanomaterials offers new opportunities to develop novel innovative packaging materials, principally derived from the manufacture of polymer-based nanocomposites. The development of polymer-based nanocomposites is rapidly emerging and has recently gained momentum in mainstream commercial applications, particularly in food packaging, and several functional nano-enabled packaging materials are already on the market.

The incorporation of nanofillers - typically inorganic and organic materials such as metals (Al, Fe, Au, or Ag), metal oxides (ZnO, Al_2O_3, TiO_2), mixed metal oxides, clays, and carbon nanotubes (CNTs) - into polymer composites confers a range of improved properties into the packaging material, including improved volume properties, surface properties, dimensional stability, chemical stability and other functional properties, which add value through improved photocatalytic, optical, electrical and/or thermal stability.

Nanofillers can be introduced into polymers at rates ranging from 1 to 10 % (in mass) depending of the type of polymer matrix, which includes thermoset polymer matrices such as polyesters (UP), polyamide, or polyurethane (PUR), and thermoplastics such as polyethylene (PE), polypropylene (PP) and polystyrene (PS).

Nanofiller-reinforced polymers compare favourably with conventional polymers in terms of gas barrier properties, flexibility, temperature/moisture stability etc. Moreover, nanoparticles may serve as means of interaction between food and the environment and can therefore play a dynamic role in food preservation and protection (active and intelligent packaging).

In light of the above, the use of nanofillers opens an opportunity for developing innovative and high performance packaging materials. Applications include nano-filler reinforced packaging (e.g. enhanced barrier properties), active packaging (e.g. antimicrobial), intelligent packaging (e.g. freshness indicators), and biodegradable packaging.

Relevant examples of the application of nanomaterials on the market and the enhanced properties addressed of different nanoparticle-polymer systems are provided in Table 1. Provided in Table 2 is a description of the main characteristics of nanofillers commonly employed in packaging applications, including information on relevant physico-chemical properties and chemical composition.

Table 1: Examples of the application and enhanced properties of nanoparticles in different polymer systems

Nanofiller		Polymer matrix	Enhanced properties	Packaging sectors
Nanoclays (MMT)	Functionalised with methyl ammonium	PLA, PP	Mechanical; Thermal; Barrier.	Food and beverage Cosmetics
	Functionalised with acetylcholine	PLA PET		
Silver (Ag)		PE, PP	Antimicrobial.	Food and beverage
Zinc oxide (ZnO)		PE, PP	Antimicrobial.	Food and beverage
Silicon dioxide (SiO_2)		PET	Thermal stability; Antimicrobial.	Food and beverage
Titanium dioxide (TiO_2)		PET,PLA	Antimicrobial; UV protection; Strength;	Food and beverage
Carbon nanotubes (CNT)		PE, PP, PVA fibres	Tensile strength; Modulus ; Mechanical.	Electronics
Precipitated calcium carbonate- $CaCO_3$		PE PP PET,PLA	Viscosity; Stiffness, Dimensional stability; Thermal properties.	Food and Beverage Cosmetics Chemicals

Table 2. Main characteristics of nanofillers commonly employed in packaging applications

Nanoclays

Identification
CAS number 1318-93-0 (montmorillonite); 57-09-0 (hexadecyltrimethylammonium bromide)

Physical appearance
Brownish powder

Material type
Layered aluminosilicate (montmorillonite) modified with an organic salt (hexadecyltrimethylammonium bromide)

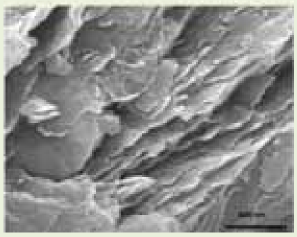
Method of production
Mechanical milling and ionic exchange (modification)

Molecular formula and weight
Aluminosilicate $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2\cdot nH_2O$ (>500)
Modifier $CH_3(CH_2)_{15}N(Br)(CH_3)_3$ (364.45)

Chemical composition
Montmorillonite ≥ 95%; hexadecyltrimethylammonium bromide ≥1%

Morphology and particle size
Platelets; 1nm (thickness) and 42 nm (interlayer distance)

Crystal structure
Monoclinic (montmorillonite)



Nano-Ag

Identification
CAS number 7440-22-4

Physical appearance
Dark grey powder

Material type
Metallic nanoparticles

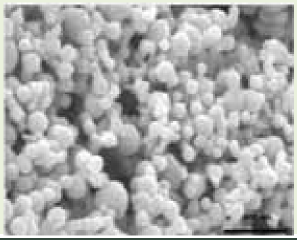
Method of production
Electrochemical deposition

Molecular formula and weight
Ag (107.87)

Chemical composition
Ag ≥99%

Morphology and particle size
Spherical; 49±13 nm

Crystal structure
Face centered cubic (FCC)



Nano-ZnO

Identification
CAS number 1314-13-2

Physical appearance
White powder

Material type
Metal oxide nanoparticles

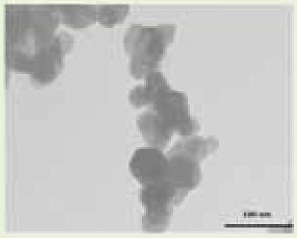
Method of production
Flame pyrolysis

Molecular formula and weight
ZnO (81.39)

Chemical composition
ZnO ≥99%

Morphology and particle size
Rounded-shaped particles (non-regular); 122±49 nm

Crystal structure
Hexagonal-zincite



Nano-SiO_2

Identification
CAS number 7631-86-9

Physical appearance
Colourless powder

Material type
Metal oxide nanoparticles

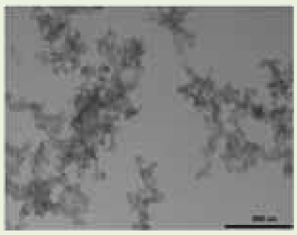
Method of production
Flame pyrolysis

Molecular formula and weight
SiO_2 (60.08

Chemical composition
SiO_2 ≥99

Morphology and particle size
Round-shaped particles; 30±4 nm

Crystal structure
Amorphous



Nano-$CaCO_3$

Identification
CAS number 471-34-1

Physical appearance
White powder

Material type
Inorganic salt

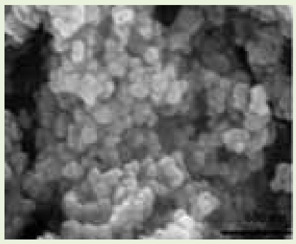
Method of production
Mechanical milling

Molecular formula and weight
$CaCO_3$ (100.09)

Chemical composition
$CaCO_3$ ≥99%

Morphology and particle size
Cubic particles; 107±20 nm

Crystal structure
Calcite



3. Structure and contents of the Best Practice Guide

The full version of the Best Practices Guide developed contains 12 chapters intended to provide the packaging industry with guidance to support the safe handling and use of nanofillers in the packaging industry. This includes technical information concerning the specific applications and properties of nanofillers, as well as new scientific knowledge on environmental, health, and safety issues.

Provided below is an outline of the structure of the Guide and key contents of each chapter.

1. Introduction and vision

This chapter outlines the purpose and scope of the guide, defines the target audience, and provides an introduction to nanotechnology in the packaging industry.

2. Types and applications of nanomaterials in the packaging industry

2.1. Nanotechnology and packaging: current and future applications
2.2. Types & specific applications of nanomaterials in polymer composites
2.3. Environment, health and safety issues of nanofillers in packaging applications

This chapter details the specific types of nanoparticles currently employed in the packaging industry as nanofillers, provides information on current and future applications and developments, and introduces the potential hazards associated with these nanomaterials.

3. General approach to managing risks from nanoparticles

3.1. Nanomaterial hazard, exposure and risk
3.2. Risk evaluation and management strategy
3.3. Roles and responsibilities of employers and workers
3.4. Good company practice

This chapter provides an overview of the basic principles of risk assessment and risk management for nanoparticles, and outlines a risk evaluation and management strategy for implementation as part of an overall company strategy for the management of health and safety.

4. Overview of the packaging lifecycle

This chapter provides an overview of the lifecycle of packaging materials, detailing the main activities and tasks involved across the various stages of the packaging lifecycle, including nanomaterial synthesis, manufacture of intermediate and final packaging products, use & service life, and end of life processing & disposal.

5. Safety during the manufacture of packaging products

5.1. Nature of the work
5.2. Exposure-prone activities
5.3. Risk management measures
5.4. Potential effects on human & environmental health and safety
5.5. Nature of use in the service life stage
5.6. Health and safety issues during the service life stage.

This chapter provides specific guidance on safe handling and use for those working in the manufacturing stage of the packaging industry. This includes identification of activities with the highest potential for exposure to nanoparticles, recommended risk management measures to minimise worker exposure, and information on potential human and environmental health effects. This chapter also addresses the service life stage, providing information on the types of consumer products produced using polymer-based nanocomposites, and an overview of health and safety issues related to consumer use.

6. Safety during end-of-life processing and disposal

6.1 Nature of processing and disposal
6.2 Exposure-prone activities
6.3 Risk management measures
6.4 Potential effects on human & environmental health and safety

This chapter provides specific guidance on safe handling and use for those working in the end of life processing & disposal stage of the packaging industry. This includes information on the main processing and disposal routes for nano-enabled packaging, and identification of the main exposure-prone tasks for workers during mechanical recycling processes. Guidance is provided on risk management measures to minimise potential exposure, and an overview of potential effects on human and environmental health and safety provided.

7. Risk communication

7.1. Importance of risk communication
7.2. Informing and protecting workers/employees during manufacture of the packaging product
7.3. Informing and protecting professional users further down the supply chain
7.4. Informing and protecting consumers

This chapter highlights the importance of effective risk communication down the packaging supply chain, and provides guidance in relation to informaing and protecting workers, professional users and consumers. This includes guidance on the development and implementation of material safety data sheets, workplace hazard signs, nanomaterial and consumer product labelling.

8. Laws, regulations and obligations of European packaging industry

8.1. Overview of key regulatory instruments
8.2. Substances and products
8.3. Product safety and quality
8.4. Worker protection
8.5. End-of-life & environment
8.6. Reporting schemes
8.7. Good practice for regulatory compliance and governance

This chapter provides an overview of the key European regulations and legislation of relevance to those working in the packaging industry. This includes the provision of advice for regulatory compliance with for laws concerning substances and products, product safety and quality, worker and environment protection, end-of-life waste management, as well as nanomaterial reporting schemes.

9. Standards & guidance to support the safe development of nanocomposites

This chapter provides an overview of key standards and published guidance documents of relevance for nanotechnologies in the packaging industry, including from ISO, CEN, BSI and OECD, which can be used in combination with the Best Practice Guide to support the safe development of polymer-based nanocomposites and packaging applications.

10. Best practice recommendations

This chapter provides a summary of best practice recommendations to support the safe handling and use of nanoparticles in packaging industries.

11. Case studies

This chapter provides three case studies which demonstrate the application of best practice during the synthesis of nanocomposites for packaging applications at laboratory-scale, pilot-scale, and industrial-scale.

12. Frequently asked questions

This chapter provides a selection of FAQs pertinent to the packaging industry in relation to safe handling and use of nanofillers, linking back to further information in the earlier chapters of the Guide.

4. Best practice recommendations for the safe handling and use of nanofillers

The full version of the NanoSafePack Best Practice Guide contains detailed best practice advice and recommendations to support the safe handling and use of nanomaterials in the packaging industry, covering the whole product value chain, including the manufacture of intermediates (nanocomposite masterbatch/ pellets), manufacture of packaging articles, service life and end-of-life processing and disposal.

Provided below is a summary of some of the key recommendations. These are by no means exhaustive and should be considered in the context of the further information outlined in the full version of the Best Practice Guide.

According with the outcomes of the NanoSafePack project and the current EU legislative framework, the following general actions are recommended to promote the safe handling and use of nanofillers:

- Gather information on the specific physicochemical, toxicological and ecotoxicological properties of the nanofillers to be used. This requires the collection and evaluation of all available and relevant information that may support the identification of hazardous properties of the nanofiller;
- Identify sources of release and evaluate the likelihood of exposure in the workplace on the basis of the specific operative conditions of the company. Aspects such as the duration (min/h) of the task, frequency (days - weeks) and amount of material handled (ng or mg), among others, should be adequately defined;
- Provide adequate measures to control the exposure, including good hygiene practices and housekeeping, organisational measures, personal protection equipment (PPE) and engineering controls (ventilation control; filtration systems).

In the specific case of the packaging industry, and on the basis of the studies conducted under the framework of the project, workers have the potential to be exposed to nanomaterials, especially during the synthesis of the nanomaterials, the feeding stage of the melt compounding process (where nanomaterials are fed into the extruder), as well as during the cleaning and maintenance operations of both the extruder and the facilities where the manufacturing of nanocomposites takes place. In the end-of-life stage, exposure may occur particular during mechanical recycling processes (e.g. drilling, cutting and/or shredding.

A summary of good practice and recommended risk management measures for key activities during the production of nanocomposites are outlined overleaf in Table 3.

Table 3: Summary of measures to control exposure during the production of nanocomposites

<table>
<tr><th></th><th>Good practice advice</th><th>Engineering controls</th><th>PPE</th></tr>
<tr><td>Nanoparticle Synthesis</td><td rowspan="2">• Information, instruction and training;
• Minimise the quantity of particulate nanomaterial in use at any one time;
• Minimise the number of people potentially exposed;
• Minimise the potential exposure time;
• Good housekeeping: containment of spills and keeping the workplace surface clean;
• Wash hands before leaving the laboratory/work area.</td><td>• Small processes: Hood or glove box;
• Large processes: Physical containment/ enclosure of the source of emission/ LEV</td><td>• Chemically resistant gloves;
• Half-mask respirator with P3 particulate filter;
• Polyethylene textiles (large processes);
• Non-cotton laboratory coats (small processes);
• Safety goggles.</td></tr>
<tr><td>Melt Compounding</td><td>• Enclosure of the source of emission/LEV</td><td>• Chemically resistant gloves;
• Half-mask respirator with P3 particulate filter;
• Non-cotton laboratory coats.</td></tr>
<tr><td>Cleaning & maintenance</td><td>• Do not brush;
• Do not use compressed air for cleaning;
• Do not use a standard vacuum cleaner;
• Use of a HEPA-filtered vacuum cleaners;
• Use absorbent materials/liquid traps;
• Information, instruction and training.</td><td>• Physical containment/ enclosure of the source of emission/ LEV</td><td>• Chemically resistant gloves;
• Half-mask respirator with P3 particulate filter;
• Non-woven Tyvek/Tychem polyethylene coveralls;
• Safety goggles.</td></tr>
<tr><td>End-of-life treatment</td><td>• Information, instruction and training;
• Avoid unnecessary energetic processes that might generate airborne dusts or aerosols;
• Minimise the quantity of particulate nanomaterial in use at any one time;
• Minimise the number of people potentially exposed;
• Minimise the potential exposure time.</td><td>• Small processes: Hood or glove box;
• Large processes: Physical containment/ enclosure of the source of emission/ LEV</td><td>• Chemically resistant gloves;
• Half-mask respirator with P3 particulate filter;
• Non-cotton laboratory coats.</td></tr>
</table>

To demonstrate the application of best practice during the preparation of nanocomposites for packaging applications at different workplaces, three case studies have been developed (presented overleaf) which cover:

i. Laboratory-scale activities, including quality analysis, functionalisation of nanomaterials, and the preparation of mixtures or formulations containing nanomaterials;

ii. Pilot-scale activities, including the processing of polymer-based nanocomposite masterbatches and re-processing to obtain final polymer-based nanocomposite films; and

iii. Industrial-scale activities, including the compounding of nanocomposites and the production of polymer-based nanocomposite films.

Each case study includes an outline of: typical work processes; potential risks; and recommendations for risk management measures.

Laboratory-scale case study

Scope

Laboratories that handle small amounts of nanomaterials (in powder form) of less than 1 kg per month. Typically these laboratories perform quality analysis or other activities such as functionalisation or the preparation of mixtures or formulations.

Typical work processes

- Reception of nanomaterials;
- Storage;
- Sampling;
- Analysis / functionalisation / mixture / formulation;
- Cleaning & maintenance;
- Waste management.

Potential risks

Activity	Risk
Opening of nanomaterial containers	Accidental spills/leakages due to the shaking of the packaging
Transfer of nanomaterial containers	Aerosol generation and skin contact
Weighing of nanomaterials	Aerosol generation and skin contact
Handling of nanomaterials	Aerosol generation and skin contact
Cleaning of workstations and bench-tops	Aerosol generation and skin contact
Waste handling	Skin contact and aerosol generation

Recommendations for risk management

- ***General recommendations***
  As a general rule, laboratory workers should use PPE (lab coats with cuffs, safety goggles, respirators, nitrile or latex gloves, closed shoes, etc.) on a precautionary basis to avoid skin contact and in case of failures to engineering controls or accidental spills. Gloves should be changed frequently.
- ***Reception of nanomaterials and storage***
  Nanomaterials should be packed in airtight containers and preferably in secondary containment. The packed material should be transferred to the storage room unopened. Access to the room where nanomaterials are stored should be restricted to authorised personnel only.
- ***Sampling***
  Nanomaterial containers should be opened and re-closed inside the workstation (e.g. inside the fume cupboard, glove box, etc.). If nanomaterials must be handled outside the workstation, appropriate PPE should be used.
- ***Analysis / functionalisation/ mixture / formulation***
  Tests/processes should be performed using appropriate engineering controls, such as containment (glove box, fume hood, etc.) or exhausted enclosures. Do not use horizontal laminar flow hoods (clean benches), as these devices direct the air flow towards the worker.
- ***Cleaning and maintenance***
  Good housekeeping procedures should be applied in laboratories where nanomaterials are handled. Work surfaces should be cleaned using HEPA-filtered vacuum and/or a wet wiping. Do not dry sweep or use compressed air.
- ***Waste management***
  All waste containers or other articles that have come into contact with nanomaterials (e.g. gloves) should be kept in a plastic bag in the work area until they are handed over to an authorised waste management company. Laundry of reusable lab coats should also be performed in-house by trained workers or specialised laundry companies.

Pilot-scale case study

Scope

Compounding and film processing pilot plant, working with up to 10 kg of nanopowders per week. Typically these pilot plants process polymer-based nanocomposite masterbatches and perform posterior reprocessing to obtain final films.
This particular pilot plant had two different extruders.

Typical work processes

- Reception of nanomaterials;
- Re-packing;
- Compounding;
- Cleaning & maintenance;
- Storage;
- Conditioning (weighing and drying);
- Film processing;
- Waste management.

Potential risks

Activity	Risk
Opening of nanomaterial containers	Accidental spills/leakages due to the shaking of the packaging
Transfer of nanomaterial containers	Aerosol generation and skin contact
Weighing of nanomaterials	Aerosol generation and skin contact
Handling of nanomaterials	Aerosol generation and skin contact
Feeding nanomaterials into the extruder	Aerosol generation and skin contact
Cleaning and maintenance of workstations and bench-tops	Aerosol generation and skin contact
Waste handling & disposal	Skin contact and aerosol generation

Recommendations for risk management

- ***General recommendations***
  Only operators trained in technical and safety aspects should work in this area. Pilot plant workers should use PPE (lab coats with cuffs, safety goggles, half mask respirators, nitrile or latex gloves, closed shoes, etc.) over the entire duration of the activity, on a precautionary basis to avoid exposure and in case of failures of engineering controls or accidental spills. Gloves should be changed frequently. Two rooms should be attached to the pilot plant for raw material and waste storage. A warehouse could be located outside the pilot plant for storage of the final nanocomposite and film.
- ***Processing plant controls***
  - Laboratory hood with a laboratory scale;
  - Various local exhaust ventilation (LEV) points placed over the extruders, including over the nanomaterial feeder, the twin screws and the nozzle, and also over the cutter of the masterbatch.
  - General ventilation;
  - HEPA filters;
  - Controlled environmental parameters: temp. approximately 20°C, dry area;
  - Access restrictions.
- ***Warehouse room controls***
  - Rooms for raw material and wastes preferably located inside pilot plant;
  - General ventilation;
  - Controlled environmental parameters: temp. approximately 20°C and obscurity, dry area;
  - Access restrictions.
- ***Reception & storage of nanomaterials***
  Nanomaterials should be packed in airtight containers and preferably in secondary containment. The packed nanomaterial should be transferred to a storage room unopened and kept separated from final nanocomposites.
- ***Feeding nanomaterials into the extruder***
  Operator should wear coverall. Always transport the nanomaterials in closed packaging, opening and feeding the nanomaterials carefully under LEV. If possible, work with nanomaterials dispersed in an appropriate solvent.
- ***Cleaning and maintenance***
  Good housekeeping procedures should be applied in pilot plant areas where nanomaterials are handled. Work surfaces should be cleaned using a HEPA-filtered vacuum and/or a wet wiping. Do not dry sweep or use compressed air. Operators should wear a coverall instead of a lab coat for higher protection, in addition to the other PPE recommended. Water used for cleaning and maintenance operations should be recovered and correctly managed by an authorised waste manager, not released into the environment.
- ***Waste management***
  Residues generated are mainly packaging, processing remains, disposable PPE, contaminated sampling materials, air filters, and nanomaterials. They should be kept in closed containers in a designed room until collected by an authorised waste manager. Re-useable lab coats must be cleaned in an industrial laundry or in-house service by trained operators.

Industrial-scale case study

Scope

Industries that handle high amounts of nanomaterials (in powder form) of more than 25000 kg per month. Typically these companies perform compounding and film processing. This particular company has two different extruders. It receives the nanomaterials in a cistern truck, and stores them in silos outside prior to use.

Typical work processes

- Reception of nanomaterials;
- Compounding (masterbatch);
- Waste management.
- Storage;
- Cleaning & maintenance;

Potential risks

Activity	Risk
Filling of nanomaterial silos	Air and soil leakages during discharge of nanomaterials from truck tankers. Skin contact and inhalation
Storage in the silo	Leakages and incorrect manipulation by unauthorised people
Transfer of nanomaterials or nanocomposite masterbatch to the extruder feeder	Aerosol generation
Feeding nanomaterials into the extruder	Release of powered nanomaterials or nanocomposites to the industry environment
Exit point of the extruder (nozzle)	Fumes containing nanomaterials
Cutting of nanocomposite masterbatch	Release of nanomaterials and airborne nanoparticles
Cleaning and maintenance of workstations and bench-tops	Aerosol generation and inhalation or skin contact
Waste handling & disposal	Direct contact with nanomaterials and risk of worker exposure (inhalation, dermal and ingestion) or environmental release

Recommendations for risk management

- ***General recommendations***
  Only operators trained in technical and safety aspects should work in this area. Workers should use PPE (lab coats with cuffs, safety goggles, half mask respirators, nitrile or latex gloves, closed shoes, etc.) over the entire duration of the activity, on a precautionary basis to avoid exposure and in case of failures of engineering controls or accidental spills. Gloves should be changed frequently. Two rooms should be attached to the main work area for raw material and waste storage. A warehouse could be located outside the industrial plant for storage of the final nanocomposite and film. If nanomaterials are received in large bags, a closed room attached to the industrial plant should be available with general ventilation and LEV over the point where the silo is fed. Restricted access and general ventilation measures should be also in place.
- ***Processing plant controls***
  - Silos located over a waterproofed floor in a supervised area (restricted access);
  - Various local exhaust ventilation (LEV) points placed over the extruders, including over the nanomaterial feeder, the twin screws and the nozzle, and also over the cutter of the masterbatch.
  - General ventilation;
  - HEPA filters;
  - Controlled environmental parameters: temp. approximately 20°C, dry area;
  - Access restrictions.
- ***Warehouse room controls***
  - Rooms for wastes preferably located inside the plant;
  - General ventilation;
  - Controlled environmental parameters: temp. approximately 20°C and obscurity, dry area;
  - Restricted access, with authorised personnel only allowed into the plant and warehouse facilities.
- ***Reception & storage of nanomaterials***
  Nanomaterials should be received in a cistern truck. The filling zone of the silo must be over a waterproofed ground with a water run-off collection system. Nanomaterials should be maintained in a controlled, well-closed silo until use. Once removed from the silo, the nanomaterials should be maintained in a controlled warehouse, separate from the final nanocomposites.
- ***Feeding nanomaterials into the extruder***
  Operator should wear coverall. Always transport the nanomaterials in closed packaging. The process of feeding the extruder should be closed and performed carefully under LEV.
- ***Cleaning and maintenance***
  Good housekeeping procedures should be applied in industrial plants where nanomaterials are handled. Work surfaces should be cleaned using a HEPA-filtered vacuum and/or a wet wiping. Do not dry sweep or use compressed air. Operators should wear a coverall instead of a lab coat for higher protection, in addition to the other PPE recommended. Water used for cleaning and maintenance operations should be recovered and correctly managed by an authorised waste manager, not released into the environment.
- ***Waste management***
  Residues generated are mainly packaging, processing remains, disposable PPE, contaminated sampling materials, air filters, and nanomaterials. They should be kept in closed containers in a designed room until collected by an authorised waste manager. Re-usable lab coats must be cleaned in an industrial laundry or in-house service by trained operators.

Further Information

The Best Practice Guide for the Safe Handling and Use of Nanoparticles in the Packaging Industry is available from:

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