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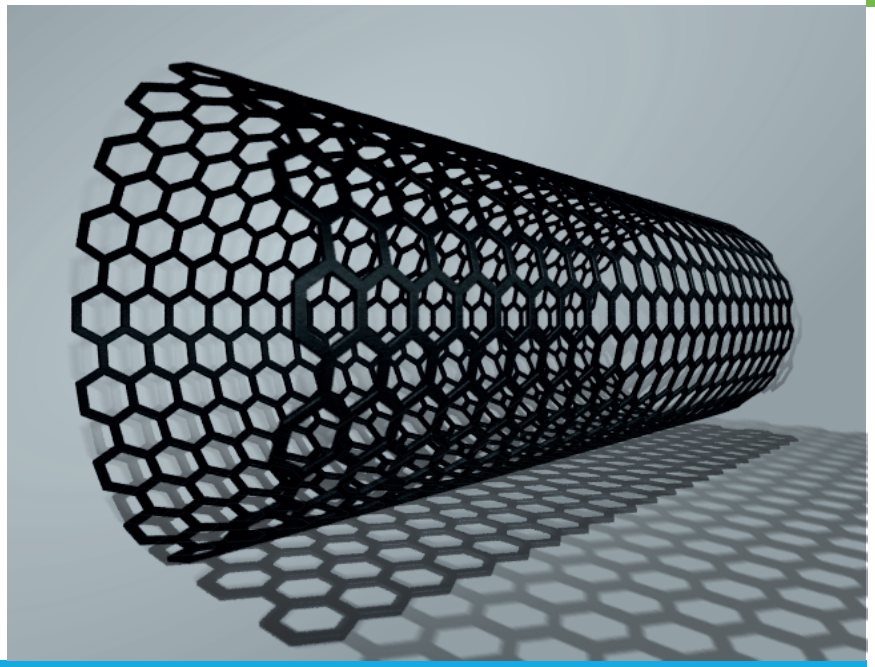
# SAFE HANDLING AND USE OF TUBALL™

Issued : **04/2018**

Reviewed : **05/2020**

# GENERAL INFORMATION



**TUBALL™ and TUBALL™ modifiers contain single wall carbon nanotubes (SWCNTs). TUBALL™ SWCNTs are 1.6 nm ± 0.4 nm in diameter and have a length of approximately 5 µm, with high product purity.**

Use of **TUBALL™** may pose a risk of exposure. This guideline identifies good practices for handling **TUBALL™** products to minimise worker exposure and environmental risk.

# SCOPE

This **health, safety and environmental guidance document** aims to set a 'precautionary principle' for handling nanomaterials safely. In the absence of nanomaterial-specific regulatory standards or other exposure standards, this guidance should be implemented by workers and laboratory researchers who handle **TUBALL™** powder.

For all mixtures involving **TUBALL™**, the precautions according to the **Safety Data Sheet** should be followed.

# POTENTIAL RISKS TO HEALTH FROM NANOPARTICLES

This document is specifically intended to be used as a living document to provide employees working with **manufactured nanomaterials (MNMs)** with an introduction to the health and safety issues of safe work with **MNMs**.

In nano-enabled products, the nanomaterials are normally bound within a matrix so there is no risk of exposure. A recent series of exposure-monitoring case studies on TUBALL™ has had very positive results. To assess exposure when handling and processing these products, abrasion and drilling tests were performed on various polymer nanocomposites, and neither free-standing nor protruding SWCNTs were detected. However, if TUBALL™ is handled in a dry state or powder form, it is possible that free nanoparticles might be released at different exposure levels depending on the types of tasks that are undertaken. In these circumstances, a precautionary approach should still be adopted.

Due to their small size, nanoparticles can become airborne and can then be inhaled, which can be dangerous to the lungs.

This inhalation risk should be the first consideration for any nanoparticle that is being manufactured or used. In dustiness testing, TUBALL™ nanotubes were observed to be medium-sized and to be entangled: these nanotubes actually produce extremely low levels of dust, which makes the inhalation risk almost nonexistent.

You cannot find any other material that is less dusty. Nevertheless, the recommended precautions need to be taken according to Appendices II–IV.

We recommend using the precautions listed on the Safety Data Sheet. Further results of (eco)toxicity testing are likely to deliver the same message: TUBALL™ MATRIX products have extremely low exposure risks or no exposure in an industrial environment.

# EXPOSURE CONTROL

## Information, instruction and training

Risk management measures (RMM) and operational conditions should be put in place to handle TUBALL™ safely.
To ensure that all control measures are properly and fully applied, clear allocation of managerial responsibilities is particularly important.
The operational conditions should include training or refresher training for those individuals who handle and are in charge of the disposal of carbon nanotubes as a substance or products containing TUBALL™.

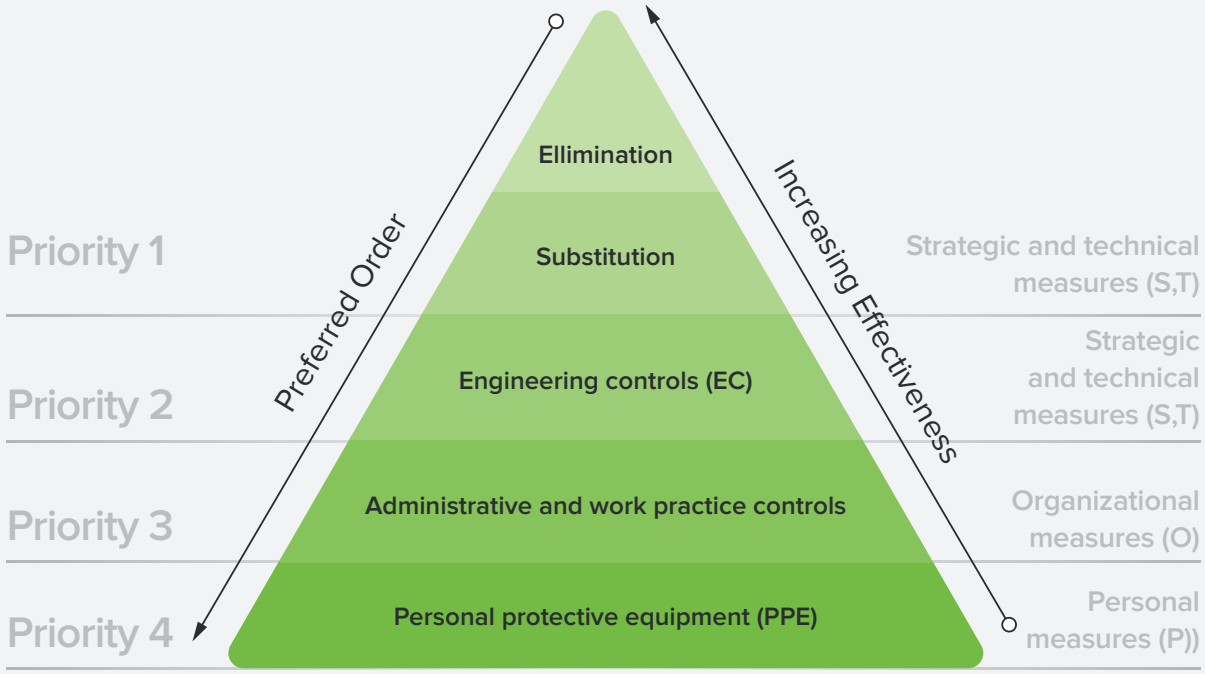



*Figure 1.* Exposure control hierarchy

# EXPOSURE CONTROL

## Information, instruction and training

**Quantitative efficiency levels:**

- The efficiency of RMM that are applicable for the involved type of nanoparticle (NP) need to be taken into account;
- Quantitative data for our type of NP is available to take the correct precautionary measures

**Selected RMM:**

- Engineering controls (EC)/technical measures
- Respiratory protective equipment (RPE)
- Skin protective equipment (SPE) – clothing, gloves and safety glasses

**Engineering controls (EC)**

- Suppression techniques
  - Moistening of the source
  - Capture sprays
  - Physical/chemical stabilisation
- Containment (without extraction)
- Local exhaust ventilation (LEV) systems

Choosing the right technique to apply depends on the process and enviromental factors.

Everyone who is involved or could be affected must be **provided with training** to ensure their safety and the safety of others.

**Employees must be duly informed about carbon nanotube properties and know, at least, the following information:**

- The names of the substances to which they are liable to be exposed and the risks to health created by exposure (the Safety Data Sheet should be available to everyone)
- Any relevant workplace exposure limit (WEL) or similar self-imposed (in-house) exposure standard that applies to each substance
- Periodic workplace exposure monitoring
- The precautions they should take to protect themselves and their fellow employees
- Personal protective equipment (PPE) that must be used and procedures to have them all available and working properly
- If a respirator is involved, then do frequent fit testing, maintenance, and cleaning

## VENTILATION

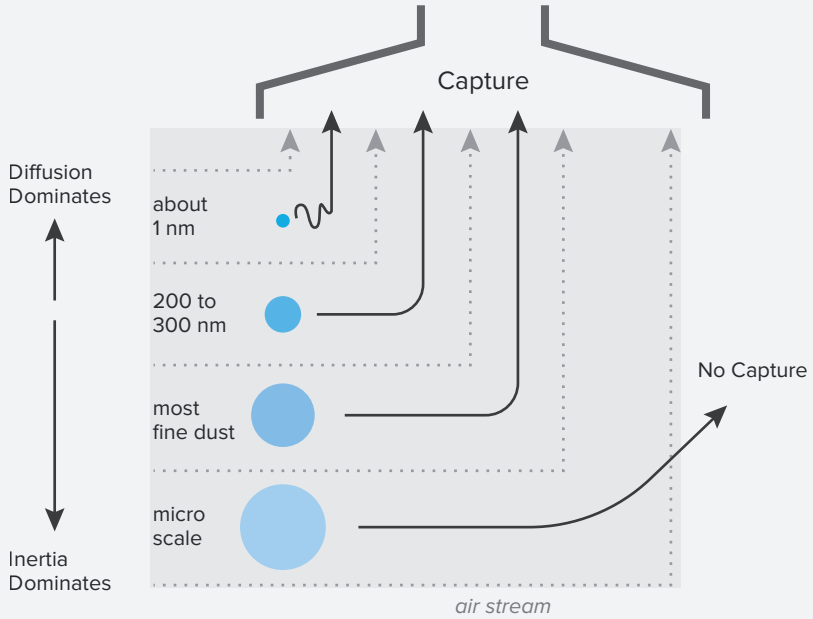



*Figure 2.*

*Paul Schulte, Charles Geraci, Ralph Zumwalde, Mark Hoover & Eileen Kuempel (2008) Occupational Risk Management of Engineered Nanoparticles, Journal of Occupational and Environmental Hygiene, 5:4, 239-249*

**When particles are smaller than 200 nm, it is more likely the diffusion will dominate and the rate of capture will increase.**

## MASKS

**Particles will bend because of the airstream and be captured by appropriate filtration equipment; electrostatic loaded filters increase the filtration efficiency.**

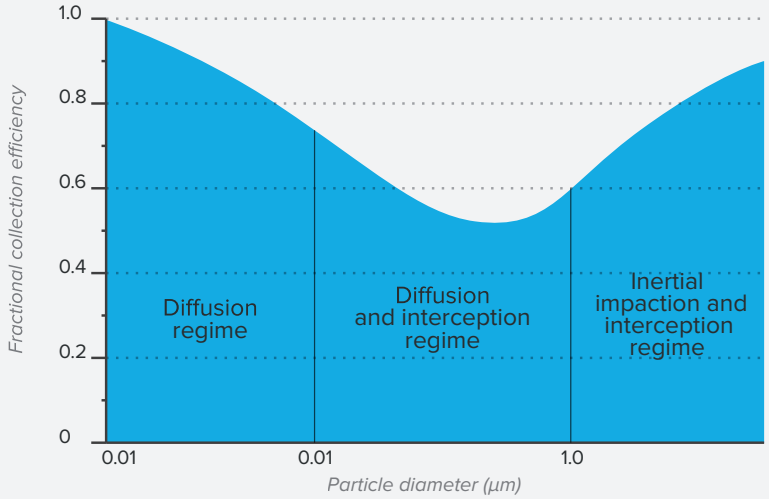



*Figure 3.*

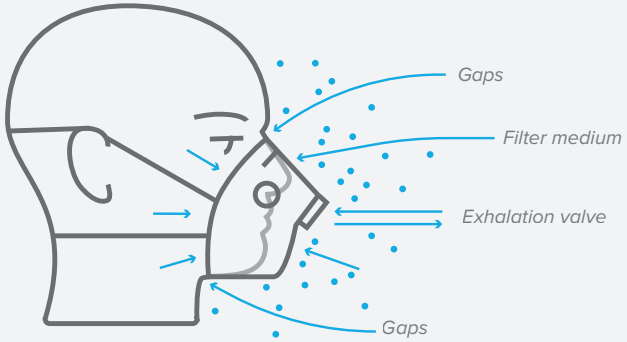



*Figure 4.*

*The solid blue curve is for electrostatic filtration, with a most penetrating particle size (MPPS) of less than 0.1 μm; the dotted blue curve is for mechanical filtration, with an MPPS of 0.3 μm.*

*KW Lee & BYH Liu (1980). On the minimum efficiency and the most penetrating particle size for fibrous filters. Journal of the Air Pollution Control Association 30(4): 377–381.*

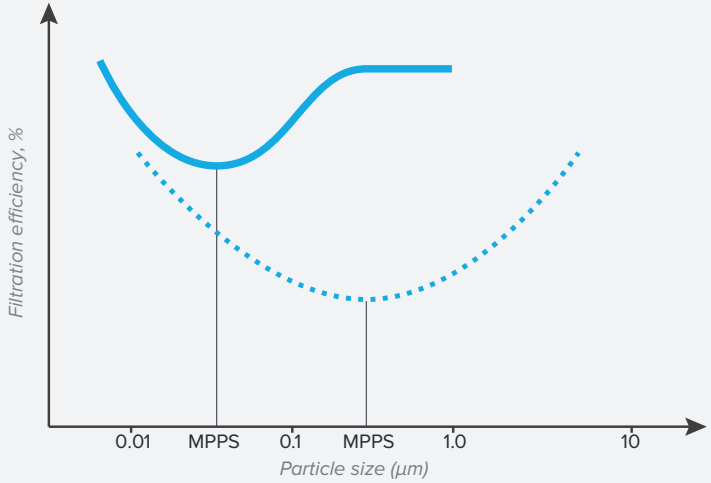



*Figure 5.*

## CLOTHING/GLOVES

**Particles can easily migrate through specific types of protective materials.**

**EN 14325** *(Protective clothing against chemicals – test methods and performance classification of chemical protective clothing, seams, joins and assemblages)*

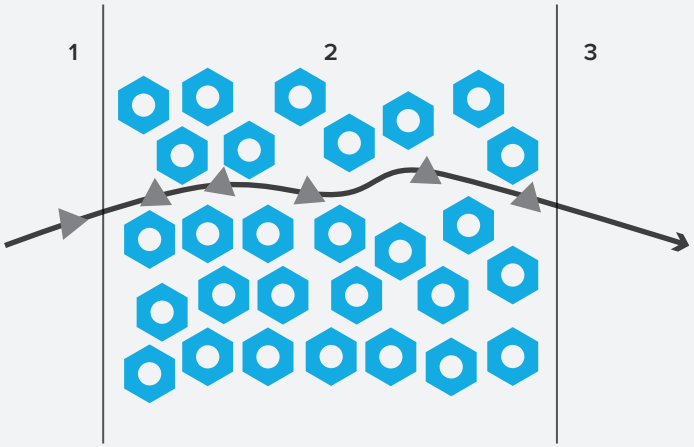



*Figure 6.*

- Non-woven PE textile protective clothing provide enough barrier protection for sub-micron particles
- Wear double gloves is recommended
- Disposable Nitrile or NBR rubber gloves

Engineering controls and Personal protective equipment (PPE). **TUBALL**™ shall not be handled without a local capture hood that has a local exhaust ventilation (LEV) through a HEPA filter.

Do not confuse the breakthrough time with the maximum recommended duration of use of a glove (see table below). The breakthrough time is obtained in laboratory test conditions and with constant contact with the chemical. Therefore, this data should only be used as a reference when selecting a glove according to the exposure conditions.

| Normalised breakthrough time at a permenation rate of 1.0 pg/(cm$^2$·min), in minutes | EN Class |
|---|---|
| > 10 | 1 |
| > 30 | 2 |
| > 60 | 3 |
| > 120 | 4 |
| > 240 | 5 |
| > 480 | 6 |

**HEPA:** High Effciency Particulate Air filter; 99.97% efficiency for 300 nm particles) or **ULPA+ filter:** Ultra Low Penetration Air filter; 99.999% efficiency of 120 nm particles

As each one of these variables increases, the chance of exposure becomes greater, as does the need for more efficient exposure control measures (Figure 7). Operations involving easily dispersed dry nanomaterials, such as powders, deserve more attention and more stringent controls.

The involved engineering controls strongly depends on the system that is being utilized.

Wearing face mask respirators, disposable clothings (overalls) are required while handling **TUBALL**™. Wash hands after handling **TUBALL**™ to prevent accidental ingestion. Eating, drinking or chewing is not allowed in the working area and laboratories.

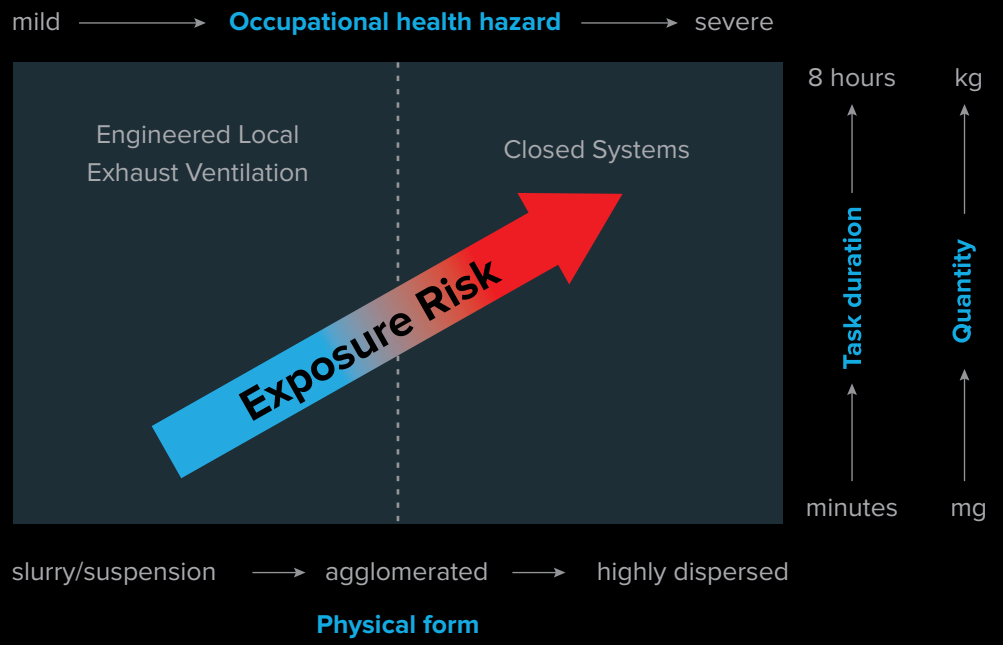



*Figure 7: Factors vs control selection*

## PPE* – clothing selection

Non-woven disposable materials have been tested in the past by various manufacturers and found to be more efficient at preventing nanoparticle penetration when compared with cotton, woven fabric or paper materials. However, they are also the least comfortable to wear for long periods of time.

Other considerations when selecting and using PPE:

- Long trousers without cuffs should be worn
- Closed toe impermeable shoes should be worn
- When disposable clothing is used: should remain in work area
  - Place in sealed bags before removing from work area to be cleaned
  - Laundering contaminated clothing must be specialized laundry facilities
  - Do not wash contaminated clothing at home!

** personal protective equipment*

## GLOVES

Nitrile (or NBR) rubber gloves should be worn while handling nanoparticles and nanostructured materials and their agglomerates or aggregates. Replace the gloves as frequently as needed. Inspect the gloves for perforation, etc., before use and prevent needle-stick-related skin punctures from injectable solutions. Double gloving will increase the protection.

More porous gloves, such as cotton, may be worn only when handling solid bound TUBALL material.

## RESPIRATOR

Whenever TUBALL™ is handled outside the local exhaust ventilation, a full-face respirator must be worn.
When handling TUBALL™ within a fume hood or an enclosure hood, an appropriate dust mask can be worn as extra protection on a voluntary basis. Dust mask filter FFP3 should be tested according to EN149. Even if a filter is maintained, repaired or replaced, it will continue to minimize the risk.

## GLASSES

Close-fitting safety glasses or prescription safety glasses with side shields should provide adequate eye protection for handling TUBALL™ powder in situations where you don't need to use a full-face respirator. A full-face respirator will provide good eye protection. Contact lenses may pose a special hazard and their use should be avoided.

## STORAGE

**Used recipients of TUBALL™ and containing products & equipment in good conditions**

- A specific standard operation procedure (SOP) need to be created;
- How to store and separate opened, collected spillage (caused incident) and still completely sealed recipients;
- Storage facility should be closed outside working hours;
- This area should be equipped with mechanical ventilation;
- The floor & walls should be smooth, resistant to the stored products and impervious;
- Once depackaged should be stored in tightly sealed and preferably rigid airtight containers;
- Stored with plastic bags double Packaging is strongly recommended;
- Every package should bear always
- A label indicating the presence of TUBALL™.

**General clearly identify a nanomaterial work area**
Pictogram example: 'Risk of exposure to NM possible at the work area'.

NANO HAZARD

## CLEANING HEPA FILTERS or PPE'S

If the **HEPA H14 - or ULPA 14+** filter is dirty and full of small dust particles, this can affect the air purification process. You can very carefully dust the HEPA filter (type of filter is min H14) from the larger dust particles that are visible on top of the filter need to be executed with all maximum precautions! Use a soft brush or a duster. If the HEPA filter is discolored grey, it should be replaced.
**Old HEPA/ULPA+ filter** will be disposed of as waste.

Protective clothing or equipment reuse depends on demonstrating that adequate decontamination has taken place: consider always a visual examination of protective clothing for signs of discoloration, corrosive effects, or any degradation of external materials.

## REMOVING or REPLACING USED PPE'S

The procedure for putting on and removing PPE should be tailored to the specific type of PPE according to this sequences.

Link to guideline:
https://www.who.int/csr/resources/publications/ebola/ppe-steps/en/

## SUMMARY OF CONTROL OPTIONS

The operational status of every type of hood should be checked regularly (see Figure 8).

### Higher order controls

- Fully isolated process areas with remote control operation booths
- Intrinsically safe systems (to protect against short circuiting)
- Negative pressure workrooms and laboratories
- Local exhaust and ventilation with HEPA filtration
- Fully ducted fume cupboards
- HEPA H14 filtered recirculating fume cabinets (for quantities of < 1 g of TUBALL™ powder)
- Glove boxes

### Lower order controls

- Non-woven disposable protective clothing
- Gloves
- Protective eyewear

### The selections of the control options depends on:

- Material state
- Tasks and operations
- Production type
- Amount of TUBALL to handle

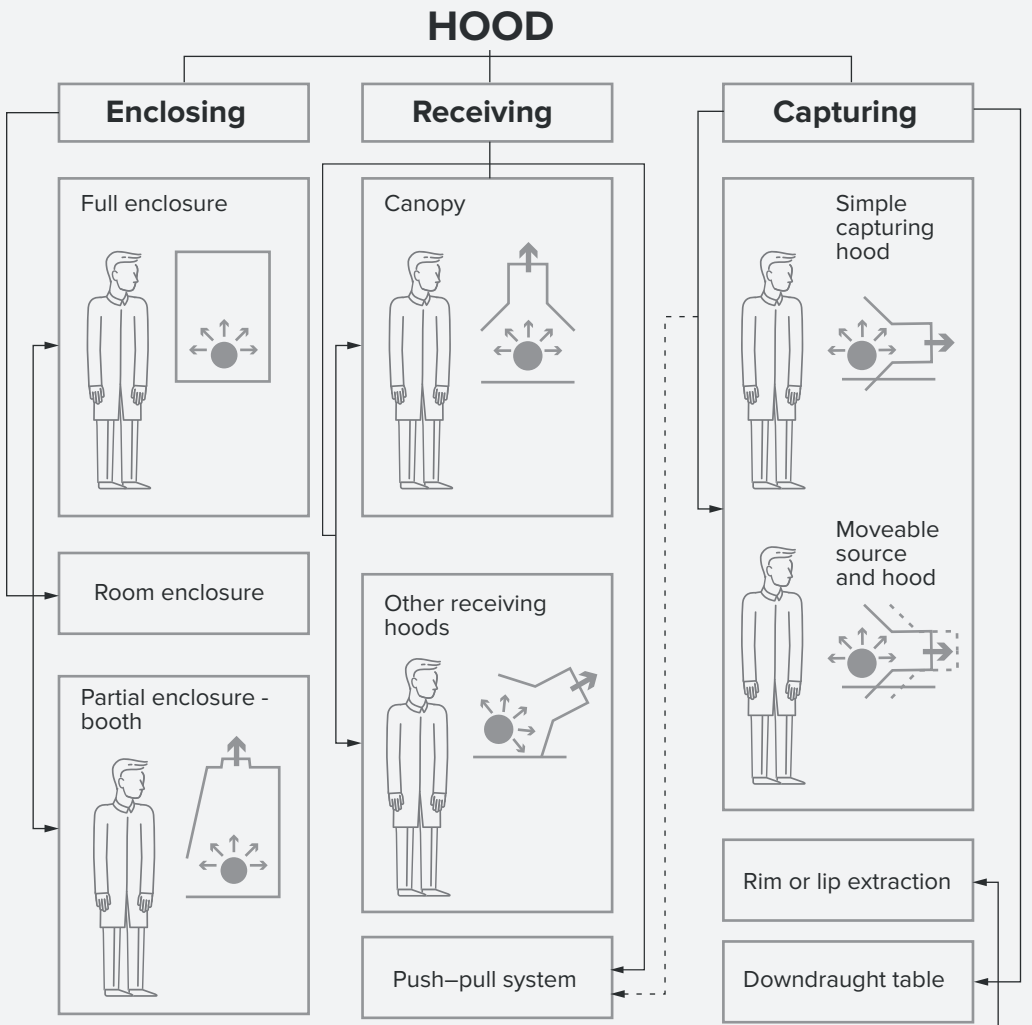



*Figure 8.*

*HSE [2011]. Report HSG258 Controlling airborne contaminants at work – A guide to *local exhaust ventilation (LEV) - see Appendix I*

# SPILLAGES AND ACCIDENTAL RELEASES

Tested and certified vacuum equipment and methods for clean-up are recommended. Dry sweeping should be avoided. When using HEPA H14 or ULPA 14+ filter, it is recommended that the effectiveness of these should be verified and, where possible, dedicated HEPA vacuums should be used for clean-up operations. It is also good practice to avoid mixing potentially incompatible materials in the vacuum or filters. All residues resulting from the clean-up of a spill or accidental release (including filters, wipes, absorbent mats and materials) should be considered as hazardous waste. PPE including safety goggles, gloves and a lab coat will be required for TUBALL™ spill clean-up.
A respirator such as a dust mask (filter FFP3), a HEPA vacuum and a sticky mat are recommended.

In case of spill or an accidental release of **TUBALL**™, use barriers to minimise air currents across the area. Consider the need to evacuate employees from that area and start clean-up as soon as it is practical to do so safely.

# DISPOSAL PROCEDURES

It is recommended to take the position that unbound carbon nanotube waste is hazardous waste. A procedure for waste storage and disposal of nanomaterial-contaminated waste should be developed, taking account of the hazardous nature of the materials and the quantities involved. Any material that has come into contact with nanoparticles should also be considered as nanomaterial waste, unless evidence suggests otherwise. This includes PPE, wetted tissues wipes and other laboratory materials used during research activities. Nanomaterial waste should not be put into the regular waste or flushed down the drain. Surface contamination should be evaluated and removed.

The waste treatment service should provide adequate documentation of the disposal conditions and incineration temperature.

## Collection and storage of nanomaterial waste prior to disposal has to be done carefully, according to the following procedures:

- Package wastes containing nanomaterial in compatible containers that are in good condition and have adequate containment to prevent the escape of materials.
- Label the waste container with a description of the waste and the hazards.
- Storage in polyethylene bags. Collect paper, wipes, PPE and other items with loose contamination in a polyethylene bag and enclose these in sealable containers.
- Wasted TUBALL™ or any TUBALL™ mixtures/suspensions need to be treated as chemical waste and never be flushed down the drain!
- Solid waste need to be put first in a sealable PE plastic bag before putting it in the chemical waste container;
- Clean always with damp cloths;
- Removing contaminated cloths in a separated chemical waste bin.

# WASTE MANAGEMENT

**Disposal of any waste containing TUBALL™ should follow and comply with all applicable local, regional and national waste regulations, including those that are not specific to nanomaterials.**

**A conservative approach should be taken and waste containing TUBALL™ should be treated as hazardous waste. The following precautionary measures should be taken:**

- Waste containing TUBALL™ must not be disposed of in the regular rubbish or down the drain.
- Every effort should be made to prevent the release of waste containing TUBALL™ to the environment.
- Waste containing TUBALL™, including dispersions, must be disposed of as chemical hazardous waste though an authorised waste treatment plant.
- Information relating to the hazardous properties of TUBALL™ to be disposed of should be passed on to anyone involved in the disposal of that material (such as the waste carrier).
- Waste containing TUBALL™ may be stored in a fume hood until ready for pickup and must be kept in a closed container.
- Any TUBALL™-contaminated PPE, coveralls and gloves, should be disposed of as “hazardous waste” and must be identified on the hazardous waste label.

# DIFFERENT TYPES OF PPE SHOULD BE WORN DEPENDING ON THE STATE OF TUBALL™ YOU ARE HANDLING

**Wet TUBALL™**

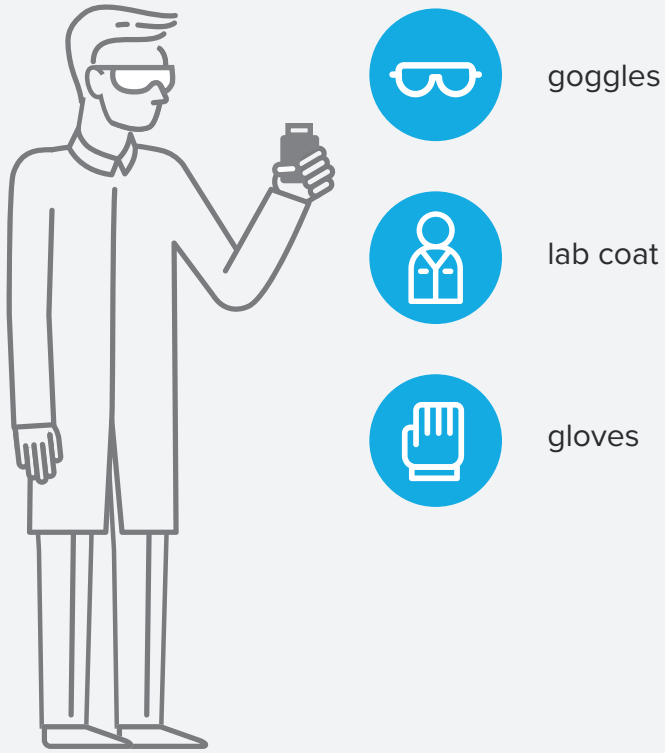



*Figure 9.*

**Dry/powdered TUBALL™**

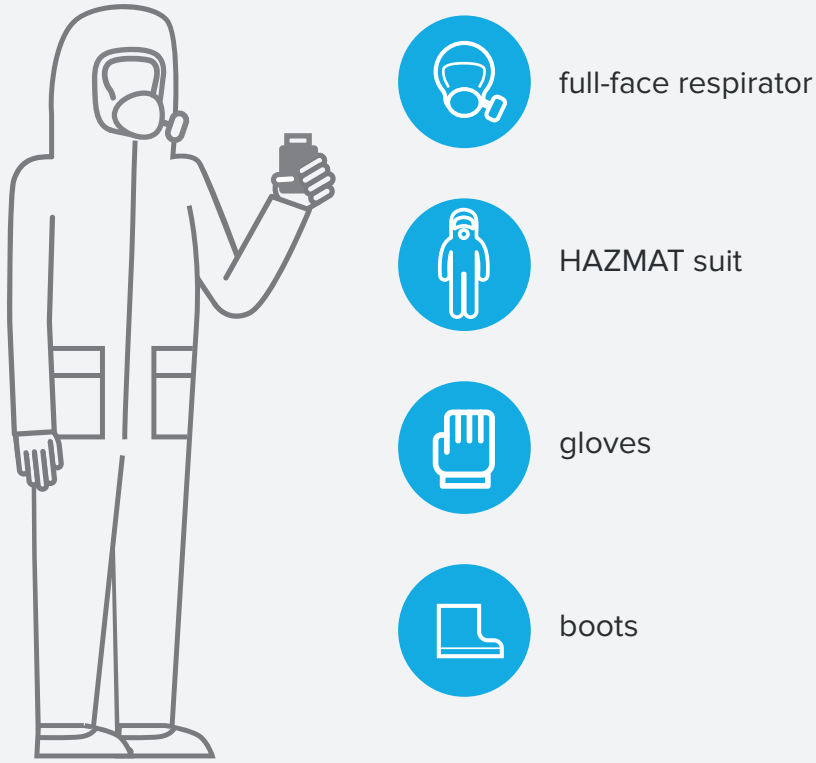
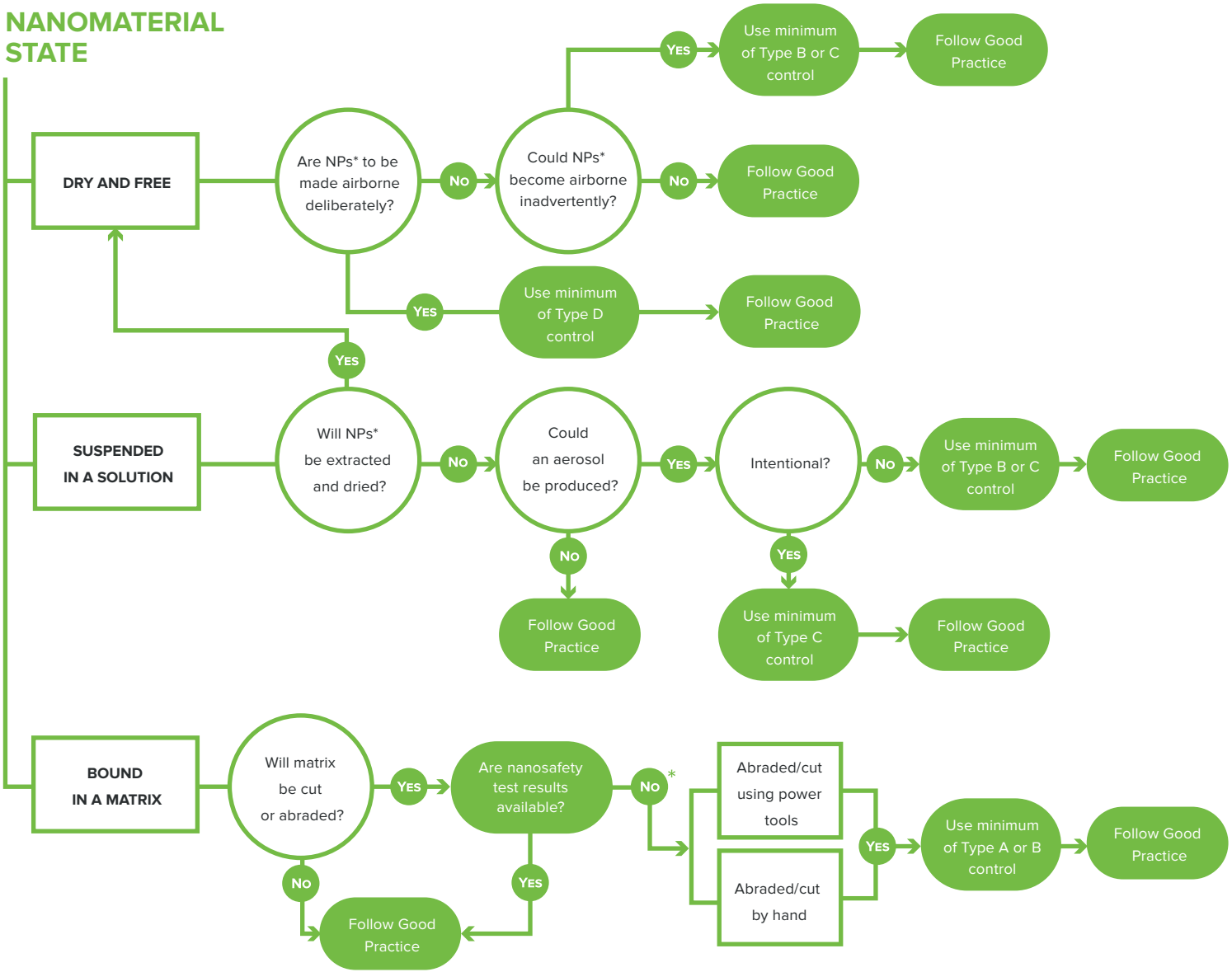



*Figure 10.*

# CONTROLLING HEALTH HAZARDS WHEN WORKING WITH TUBALL™: QUESTIONS to ASK BEFORE STARTING

| Here are some questions you should ask yourself before starting work with nanomaterials | Here are some options you can use to reduce exposure to TUBALL™ in the workplace – these options correspond with the questions on the left | | |
|---|---|---|---|
| | CONTROL BAND 4<br>**DRY POWDER** | CONTROL BAND 2–3<br>**SUSPENDED IN LIQUID** | CONTROL BAND 1<br>**PHYSICALLY BOUND/ENCAPSULATED**<br>(typically the lowest potential for exposure) |
| **FORM**<br>Have you done a job hazard analysis?<br>What is the physical form of the nanomaterial?<br>How much are you using? Can you reduce exposure to the nanomaterial by changing its form (creating a suspension) or by reducing the amount used in each batch? | **See the Appendix I flowchart and Appendix IV in the SH&U guideline for TUBALL™ for general information** | | |
| **WORK ACTIVITY**<br>How are you using TUBALL™? Could your work activity cause exposure? Is the likelihood of exposure low or high? Can you change the way to do the activity to reduce the exposure? | **Applies to dry TUBALL™ powder:**<br>- **High potential for exposure:** dumping bags of TUBALL™ powder, manual bagging/transferring or sieving<br>- **Lower potential for exposure:** scooping/weighing of TUBALL™ powder | **Applies to TUBALL™ suspended in liquids:**<br>- **Higher potential for exposure:** Spraying, open-top sonication, producing a mist<br>- **Lower potential for exposure:** liquid spillage cleaning, blender cleaning, pipetting small amounts, brushing | **Applies to physically bound/encapsulated TUBALL™:**<br>- **Higher potential for exposure:** Cutting, grinding, sanding, drilling, abrasive blasting, thermal release<br>- **Lower potential for exposure:** use of solid TUBALL™ MATRIX products, manual cutting and sanding polymer nanocomposites, painting/coating with a roller or brush |
| **ENGINEERING CONTROLS**<br>Based on the form and work activity, which engineering controls will be effective?<br>What are the key design and operational requirements for the control?<br>How does the non-nanomaterial base material or liquid affect exposure? | **Applies to dry TUBALL™ powder:**<br>**Are exposure monitoring studies available?**<br>**YES** - Follow Good Practice<br>**NO** - **Could TUBALL™ nanoparticles become airborne deliberately?**<br>**YES** - Control type D is applicable<br>**NO** - **Could TUBALL™ nanoparticles become airborne inadvertently?**<br>**NO** - Follow Good Practice<br>**YES** - Control types B or C are applicable | **Applies to TUBALL™ suspended in liquids:**<br>**Are exposure monitoring studies available?**<br>**YES** - Follow Good Practice<br>**NO** - **Could an aerosol be produced?**<br>**NO** - Follow Good Practice<br>**YES** - **Intentionally?**<br>**NO** - Control types B or C are applicable<br>**YES** - Control type C is applicable | **Applies to physically bound/encapsulated TUBALL™:**<br>**Are exposure monitoring studies available?**<br>**YES** - Follow Good Practice<br>**NO** - Perform an exposure monitoring study<br>OR:<br>- Control type A is applicable IF there is low potential for exposure<br>- Control type B is applicable IF there is high potential for exposure |
| **ADMINISTRATIVE CONTROLS**<br>Have you considered the role of administrative controls? Have you set up a plan for waste management? Have you considered what to do in the event of a spill or how you will maintain your equipment and machinery? | **Applies to TUBALL™ powder and TUBALL™ suspended in liquids:**<br>- Establish an Exposure Control Plan and a Risk Assessment!<br>- Store material in sealed containers/bags (double contained)<br>- Use absorbent paper/sticky mats<br>- Use SOPs to ensure good practices<br>- Follow rules of good housekeeping | - Carry out frequent training for employees<br>- Using a specific sign/pictogram, e.g. 'Risk of exposure to NM possible at the work area', is recommended<br>- Use sealed/closed containers and secondary containment<br>- Clearly label all containers with any TUBALL™ inside | **Applies to physically bound/encapsulated TUBALL™:**<br>Follow Good Practice |
| **PERSONAL PROTECTIVE EQUIPMENT**<br>If the measures above do not effectively control the hazard, what PPE can be used? Have you also considered PPE for the non-nanomaterial base material or liquid? | **Applies to dry TUBALL™ powder:**<br>- Full nonwoven coverall and hood<br>- P3 respirator type - see the table in Appendix V<br>- Double gloves (nitrile - or NBR rubber)<br>- Disposable over-booties for shoes<br>- Close-fitting safety glasses<br>- Long trousers (no cuffs) | **For all mixtures involving TUBALL™, the precautions according to the Safety Data Sheet should be followed**<br>Section 8 of the SDS is relevant only | - **Lower potential for exposure:**<br>Section 8 of SDS is relevant only<br>•<br>•<br>•<br>• |
| **WASTE & DISPOSAL** | **Disposal of any waste containing TUBALL™ should follow and comply with all applicable local, regional and national waste regulations, including those that are not specific to nanomaterials.** See the SH&U guideline for TUBALL™ for precautionary measures. | | |
| **SPILL & ACCIDENTAL RELEASE**<br>Spill kit | - Evacuate employees from an area with accidental release or spill of TUBALL™<br>- Use tested and certified vacuum equipment<br><br>Recommended **PPE for TUBALL™ spill clean-up:**<br>- Safety goggles<br>- Nitrile gloves<br>- Nonwoven lab coat or coverall | - Dry sweeping should be avoided<br>- Use tested and certified vacuum equipment<br>- HEPA vacuum cleaners with minimum H14 filters are most effective<br>- A sticky mat – daily new<br>- A respirator such as a dust mask (filter P3) | **Applies to physically bound/encapsulated TUBALL™:**<br>Follow Good Practice |
| | **All residues resulting from the clean-up of a spill or accidental release (including filters, wipes, absorbent mats and materials) should be treated as hazardous waste** | | |

## Nanomaterial control measures selection flowchart




## CONTROL TYPES

*least effective*

**A** Capturing and receiving hood, ideally discharged to a safe place outside. HEPA or ULPA+ filtration to be used if recirculated back to the workplace.

**B** Partial enclosure with HEPAor ULPA+ filtration with recirculation to the workplace.

**C** Partial enclosure with HEPA or ULPA+ filtration and discharged to a safe place outside.

*most effective*

**D** Full enclosure with HEPA or ULPA+ filtration and discharged to a safe place outside.

* *To obtain more details about which materials have been nanosafety tested, please contact the HS&E Department OCSiAl Group.*

*Source: Working Safely with Nanomaterials in Research & Development (2nd Edition) page 40 - UK Nanosafety Group 2016.*

## List of technical measures for controlling occupational exposures to engineered nanomaterials from laboratory to large-scale facilities*

| STAGE/PROCESS | LABORATORY | PILOT PLANTS | INDUSTRIAL SETTING (MEDIUM-SCALE PRODUCTION) | INDUSTRIAL SETTING (LARGE-SCALE PRODUCTION) |
|---|---|---|---|---|
| **Material unpacking (dry powder)** | Ventilated laboratory hood (partial enclosure) | | HEPA-filtered downflow booth (or rooms)/Non-ventilated enclosure for low, slightly or non-toxic engineered nanomaterials | |
| **Weighing (dry powder, liquid dispersions) Transferring** | Ventilated laboratory hood (partial enclosure)<br>Local exhaust enclosure (glove box)<br>Biological safety cabinet | HEPA-filtered downflow booth<br>Walk-in hood | Custom-fabricated enclosures HEPA-filtered downflow booth | |
| **Sonicating** | Ventilated laboratory hood (partial enclosure) | | Fully enclosed operation | |
| **Mixing (dry powder)**<br><br>**Mixing (liquid dispersions)** | Ventilated laboratory hood (partial enclosure)<br>Local exhaust enclosure (glove box) | HEPA-filtered downflow booth<br>Movable LEV systems (extendable arms) | Custom-fabricated walk-in booths | |
| **Production (chemical and physical synthesis)** | Ventilated laboratory hood (partial enclosure) | Ventilated enclosure located inside a downflow room<br>Receiving hood (hot process) | Fully enclosed reactor | |
| **Packing/bag filling** | Ventilated laboratory hood (partial enclosure) | HEPA-filtered downflow booth<br>Ventilated collar-type exhaust hoods<br>Continuous liner product off-loading system | Custom-fabricated enclosures / Downdraft hood / Ventilated collar-type exhaust hoods / Continuous liner product off-loading system | |
| **Spraying** | Ventilated laboratory hood + built-in water wash-down systems | Walk-in hood | Custom-fabricated walk-in booths | Custom-fabricated walk-in booths (built-in water wash–down systems) |
| **Machining (sawing, grinding, etc.)** | Ventilated laboratory hood (partial enclosure)<br>Movable LEV systems (extendable arms) | Custom-fabricated movable LEV systems (extendable arms) | Movable LEV systems (extendable arms)<br>Custom-fabricated walk-in booths (wet suppression) | |
| **Compounding/ injection moulding** | Custom-fabricated movable LEV systems | Canopy hood – receiving hood (hot process) | | Fully enclosed operation |

Source: Life NanoRISK guide – project partly input from ITENE during this project, see page 46

**Proper maintenance of the technical measures listed this table must be conducted, including additional system checks to ensure adequate system performance. The following table (Appendix III) shows a list of technical measures that can be used in relevant activities in the life cycle of engineered nanomaterials.*

## List of technical measures for controlling occupational exposures to engineered nanomaterials in relevant operationsin production facilities

Note that the selection of the technical measures should be based on the specific workplace conditions and on the results of the risk assessment conducted by a competent person who has knowledge of the operative conditions and exposure situations.

| | VENTILATED TECHNICAL MEASURES | | | | | | | | | NON-VENTILATED TECHNICAL MEASURES | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Laboratory fume hood or cupboard | Local exhaust enclosure (glove box) | Receiving hood (hot process) | Movable LEV systems | Walk-in hood/booth | HEPA or ULPA+-filtered downflow booth | Ventilated collar-type exhaust hoods | HEPAor ULPA+-filtered downflow rooms | Custom fabricated enclosures (fully — partial) | Continuous liner product off-loading system | Inflatable seals |
| **Material unpacking** | ✓ | ✓ | | | | ✓ | | ✓ | ✓ | | |
| **Weighing (dry powder and liquid dispersions)** | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | | | |
| **Transferring** | ✓ | | | | ✓ | | | | ✓ | | |
| **Sonicating** | ✓ | | | | | | | | ✓ | | |
| **Mixing (dry powder and liquid dispersions)** | ✓ | ✓ | | ✓ | ✓ | | | ✓ | | | |
| **Synthesis (dry/liquid)** | ✓ | | ✓ | | | | | | ✓ | | |
| **Packing/bag filling** | ✓ | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Spraying** | | | | | ✓ | ✓ | | | | ✓ | |
| **Machining** | ✓ | | | ✓ | ✓ | | | | ✓ | | |
| **Compounding/injection moulding** | | | ✓ | | | | | | | | |

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**Exposure potential depending on product form and operation carried out**

| PRODUCT FORM | TASKS / OPERATIONS | EXPOSURE POTENTIAL |
|---|---|---|
| **DRY POWDER** | **Handling:** opening bags, weighing, measuring, packaging, transferring<br>**Processing:** blending, mixing; tasks that are likely to produce airborne carbon nanotubes<br>**Cleaning/maintenance:** powder spillage | **HIGH** |
| **SUSPENSION (LIQUID/PASTE)** | **Handling:** opening bags, packaging, transferring<br>**Processing:** aerosolisation, mixing, spraying, coating<br>**Cleaning/maintenance:** liquid spillage, blender cleaning | **MODERATE** |
| **EMBEDDED IN POLYMERIC MATRIX** | **Processing:** cutting, grinding, sawing, spinning, weaving<br>**Cleaning/maintenance:** extruder screw cleaning | **LOW** |
| | **Handling:** packaging, transferring, weighing, opening bags<br>**Processing:** moulding, extrusion<br>**Cleaning/maintenance:** granule spillage | **LOW** |

SAFE HANDLING AND USE OF TUBALL™ / **APPENDIX V**

**List of PPE types to be used in relevant activities in laboratories and in industrial facilities**

| RPE type | | Filter type | Unpacking (dry powder and liquid dispersion) | Weighing (dry powder) | Weighing (liquid dispersion) | Transferring (dry powder) | Transferring (liquid dispersion) | Sonicating | Physical and chemical synthesis operations | Mixing (dry powder) | Mixing (in liquid) | Packing / Bag filling | Machining operations (sawing, grinding, etc.) | General cleaning and maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Filtering devices (air purifying) | Filtering face mask | P1 | | | | | | | | | | | | |
| | | P2 | | | | | | | | | | | | |
| | | P3 | ✓ | ✓ | ✓ | | | ✓ | | | | | ✓ | ✓ |
| | Half-face mask | P1 | | | | | | | | | | | | |
| | | P2 | | | ✓ | | ✓ | ✓ | | | | ✓ | | |
| | | P3 | | ✓ | | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ |
| | Full-face mask | P1 | | | | | | | | | | | | |
| | | P2 | | | | | | | | | | ✓ | | |
| | | P3 | | | | | | | ✓ | ✓ | ✓ | ✓ | | ✓ |

Source: Life NanoRISK guide table 25/26

**For further information and professional services which can support the safe handling and control of nanomaterials, see the following links:**

- Life NanoRISK guideline (2016)
- BAuA (2015) Safe handling of nanomaterials and other advanced materials at workplaces
- BSI (2007) Guide to safe handling and disposal of manufactured nanomaterials
- BSI (2012) Disposal of manufacturing process waste containing manufactured nano-objects
- EC (2014) Working safely with manufactured nanomaterials
- GoodNanoGuide (est. 2008)
- HSE (2013) Using nanomaterials at work
- ISO (2008) Health and safety practices in occupational settings relevant to nanotechnologies
- NanoSafePACK (2015) Best practice guide for the safe handling and use of nanoparticles in packaging industries
- NanoSmile (est. 2008)
- NIOSH (2012) General safe practices in working with engineered nanomaterials in research laboratories
- NIOSH (2013) Current strategies for engineering controls in nanomaterial production and downstream handling processes
- NIOSH (2016) Building a safety program to protect the nanotechnology workforce: a guide for SMEs
- OECD (2010) Compilation of nanomaterial exposure mitigation guidelines relating to laboratories
- SWA (2012) Safe handling and use of carbon nanotubes
- UK Nanosafety Group (2016) Working safely with nanomaterials in research and development
- ‘INRS (2012) Nanomaterials, definitions, toxicological risk, characterization of occupational exposure and prevention measures’