Working Group: "Disposal of Nanowaste"

Draft conceptual study

Environmentally sound and safe disposal of waste from manufacturing, and industrial and commercial processing of synthetic nanomaterials

Version for practical test
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1. Introduction

1.1 "Synthetic Nanomaterials" Action Plan

On 9 April 2008, the Swiss Federal Council issued its „synthetic nanomaterials“[1] Action Plan. The plan shows how responsible progress can be secured for synthetic nanomaterials in the coming years, and takes account both of the diverse economic interests, and also of the need for protection of consumers and workers, and of the environment. The Action Plan provides for the intensification of risk research, communication and research promotion, particularly for those uses of nanotechnology that contribute to the conservation of resources and protection of public health, and also envisages legal measures in various areas. In an initial phase, the obligation of the importers of nanomaterials and their applications to apply self-control is to be concretized. This group of measures also contains regulations on the disposal of products containing synthetic nanomaterials according to the following reasoning: “During the disposal of products containing synthetic nanomaterials, hazardous nanoparticles can be released to the environment or hinder the recycling of composite materials and plastics. An investigation is necessary as to how the proper disposal of synthetic nanomaterials can be secured.” (see Action Plan, page 10).

1.2 Exploratory conceptual study

Towards the end of 2008, the FOEN appointed the Working Group “Disposal of Nanowaste“. The Group includes representatives from the cantons (the KVU is represented by the specialist environmental agencies of the Cantons of Basel City and Vaud), Federal agencies (FOEN, seco, SUVA, swissmedic) as well as industrial associations (chemical, textile, metal/machinery, electronics, paper, packaging, paints/varnish) and the waste industry (waste incineration, reprocessing of scrap, disposal of special waste). In an initial phase, the Working Group prepared the present Exploratory Study, which is intended to be used as the basis of enforcement guidelines for the environmentally sound and safe disposal of waste resulting from the production, and industrial and commercial processing, of synthetic nanomaterials.

The present version of this document is intended to indicate to and provide companies which produce, further process or dispose of nanomaterials with information as to how they should proceed with wastes from their processes that contain free or releasable nanoparticles and -rods („nanowaste“) on the basis of current knowledge. In question are, for example, reject charges, production waste and residues from research and development, for which the type, quantity and concentration of nanoparticles and -rods call for specific measures. The Conceptual Study is not concerned with the disposal of consumer goods containing nanomaterials, since it is not possible at present to stipulate – if at all necessary – specific disposal measures, owing to knowledge gaps concerning the type and quantities of such products and the behavior of nanomaterials in waste incineration plants, or in other disposal installations.

The Working Group identified substantial knowledge gaps on the type and quantities of nanowaste, and on the behavior of nanomaterials in waste treatment installations. Prior to the preparation of an enforcement aid for the use of the responsible authorities, the knowledge gaps must be closed as far as possible. The Working Group therefore suggests using the

[1] Download: http://www.bafu.admin.ch/publikationen/publikation/00574/index.html?lang=de (www.umwelt-schweiz.ch/div-4002-d)

present **conceptual study** to perform a practical test with the participation, on the one hand, of the producers, and also of industrial and commercial processors, of nanomaterials, and, on the other hand, companies in the disposal business (disposers of special waste, special waste incineration plants, etc.).

At this juncture, the FOEN and the external project management wish to thank the members of the Working Group, who have accompanied and supported the preparation of this document, for their valuable support and critical assessment of the work, very warmly.

2. General notes on Nanomaterials

2.1. Physical and chemical properties

According to the ISO [2] definition, **nanomaterials** are understood to mean either **nanostructured materials** or **nanoobjects**.

Nanoobjects are materials of nanoscale (approx. **1 – 100 nm**) in one, two or three external dimensions. Typical examples are: **nanoplatelets**, **nanorods, nanofibres** and **nanoparticles**.

- **Nanoparticles** are of nanoscale in **three external spatial dimensions** (e.g. fullerenes and carbon black, which consist of carbon, the so-called “quantum dots” in semiconductor material or nanoscale metallic silver).

- **Nanorods** and **nanofibres** are of nanoscale in **two dimensions** (e.g. carbon nanotubes CNT, e.g. tubular arrangements of carbon atoms, or nanowires, having several 10 nm diameter, made from metals such as cobalt, gold or copper, or of silicon).

- **Nanoplatelets** or **nanolayers** are of nanoscale in **one dimension** only (e.g. graphite platelets).

Nanostructured materials have an internal/intrinsic(?)nanoscale structure . Typical examples are aggregates and agglomerates of nanoobjects or composites containing nanoobjects.

In handling nanomaterials (including disposal), nanorelevant risks arise mainly in connection with **nanoparticles and nanorods** (abbreviated **NPR**). The abbreviation NPR is used in the following text throughout to agree with the “Precautionary Matrix for Synthetic Nanomaterials "[3], issued by the FOPH and FOEN, which may be used as an aid in the estimation of the nanospecific precautionary need in handling nanowaste (see Chapter 2.4).

The following figure 1 was taken from the Guidelines to the Precautionary Matrix.

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[2] ISO/TC 229: ISO/TS27687, Nanotechnologies – terminology and definitions for nanoparticles, Geneva 2007

[3] http://www.bag.admin.ch/themen/chemikalien/00228/00510/05626/index.html Version 2, 2010

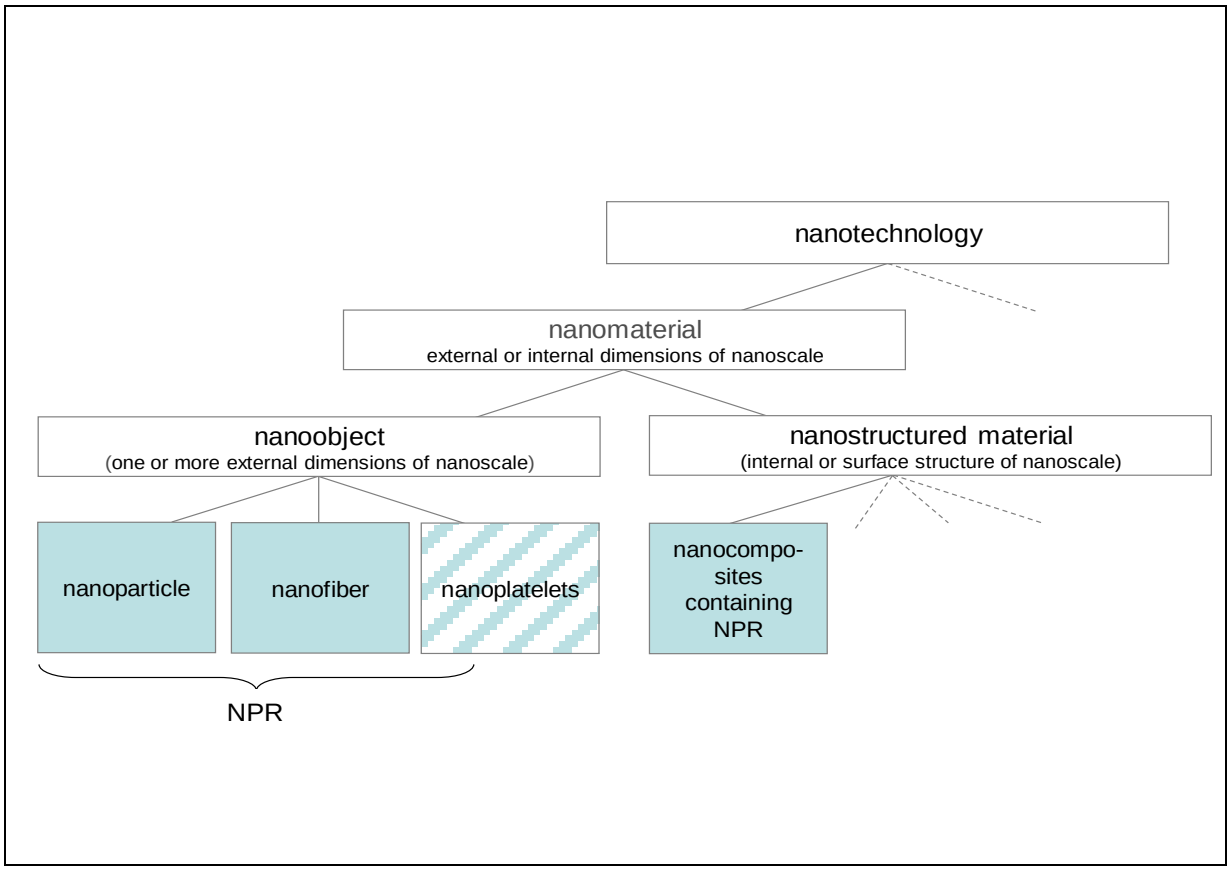

Fig. 1: Nanomaterials containing NPR are relevant to disposal as dicussed in the present Exploratory Study. (Source: FOPH/FOEN: Guidelines tothe Precautionary Matrix for Synthetic Nanomaterials , version 2.1, 2011)

Chemically, nanomaterials can consist, for example, of pure or mixed oxides, salts, metals and organic substances. In accordance with the recommendations of the ISO (TR 2885, "Health and safety practices in occupational settings relevant to nanotechnologies"; see list of publications in Chapter 5), nanomaterials are categorised – primarily – according to their chemical composition, and – secondarily – according to their form:

a. Carbon compounds (e.g. fullerenes; carbon black; carbon nanotubes).

b. Oxides (metal oxides and silicates in various, sometimes very complex, forms, such as rods (nanorods), in brushes (nanobrushes), spiral springs (nanosprings) or belts (nanobelts))

c. Metals (such as nanoparticles or nanowires)

d. Semiconductors (mostly such as so-called quantum dots)

e. Organic polymers (straight or branched fibres (so-called dendrites))

f. "Bio-inspired nanomaterials", (nanomaterials with included or adsorbed biological substances; micelles, liposomes, protein particles)

Examples of nanomaterials important from a quantity standpoint are carbon compounds, silver, silicates, titanium dioxide, zinc oxide and cerium oxide. (Source: Basic Report of the

FOEN/ FOPH, ("Grundlagenbericht", see list of publications in the Annex. In this publication, data of 2006 were evaluated).

This report lists the following examples of areas of application:

- Medicines and pharmaceuticals
- Foodstuffs and packagings
- Textiles
- Cosmetics
- Electronics
- Building and composite materials
- Domestic chemicals and appliances
- Agricultural consumables

2.2. Possible risks in handling nanomaterials[4)]

Under the precautionary principle, possible hazardous effects on the environment and health are minimized through responsible handling of nanowaste (see Art. 1 Para. 2 LPE).

Risks to health, safety and the environment arise primarily from nanomaterials with free or releasable nanoparticles and nanorods (free or releasable NPR).

Owing to the particular properties of NPR, the following main potential risks should be assumed:

a) Nanoparticles can directly penetrate biological barriers, and thus for example be carried from the lungs direct into the bloodstream (translocation).

b) The comparatively large specific surface area (surface area/mass) of nanoparticles can lead to intensified effects in the case of substances with toxic properties.

c) In individual cases, the size reduction of the particles may be accompanied by increased bioavailability.

d) Nanoparticles can have different chemical and physical properties from the same material on a micro- or macroscale. It is precisely for those materials that are manufactured especially for their new technically interesting properties, that the risk of new unknown effects is immanent.

e) Certain CNT (carbon nanotubes) and nanowires, owing to their small dimensions (ratio of the lengths of their sides) may have similar effects in the lungs to asbestos fibers.

f) Attention must be paid to the risk of dust explosions (as in all applications of inflammable powders or powdery substances).

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4) The summary below is based on the following FOEN/BAG publications: "Fundamentals Report on the “synthetic nanomaterials” Action Plan, Bern, 2007 and the BSI (British Standards Institution): "Guide to safe handling and disposal of manufactured nanomaterials”, London, 2007 (see list of publications in the Annex)

Precautionary Matrix for Synthetic Nanomaterials An initial version – The Precautionary Matrix – was published in 2008 by the FOPH and FOEN as part of the Action Plan.[5] The Precautionary Matrix facilitates the preparation of estimates of the nanospecific precautionary need requirement in the handling of nanomaterials and waste. The new version 2.0 was published in April 2010. At the same time, the electronic version was issued [6]. This renders the filling out and evaluation of the Precautionary Matrix much simpler.

The guiding principle is explained in the Guidelines to the Precautionary Matrix as follows:

The present precautionary matrix helps businesses to assess the need for nanospecific measures (precautionary need) for synthetic nanomaterials and their applications for employees, consumers and the environment, based on selected parameters. In addition it helps in the identification of possible sources of risk in the development, production, use and disposal of synthetic nanomaterials. However, this pragmatic approach should not in any way be taken as equivalent to a risk assessment process.

The risk potential can be classified to show what action is appropriate:

***"Class A":** The nanospecific need for action can be rated as low, even without further clarification.*

***"Class B":** Nanospecific action is needed. Existing measures should be reviewed, further clarification undertaken and, if necessary, measures to reduce the risk associated with development, manufacturing, use and disposal implemented in the interests of precaution.*

(Guidelines to the Precautionary Matrix, version 2.1, 2011, page 7)

and

In all cases in which it is not possible to conduct an assessment according to the guidelines in the matrix (e.g. low, medium, high) because the information is not available, the value that would ultimately give the highest precautionary need must be used. (Guidelines to the Precautionary Matrix 2.1, 2011, page 15).

3. Disposal of nanowaste

3.1. Nanowaste

This Conceptual Study is concerned with waste that arises in production and in industrial and commercial processing of nanomaterials and that contain **free or releasable nanoparticles or -rods (NPR)** (see Fig. 1). These wastes are designated as **Nanowastes**.

This treatment is restricted to waste of **synthetic nanomaterials** *(manufactured nanomaterials, engineered nanomaterials),* **which arise in production and processing**. This waste consists, for example, of production waste, reject charges, filter residues, wiping cloths or solvents or residues from research and development, where the type, quantity and concentration of NPR make nanospecific measures necessary.

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[5] Download: http://www.bafu.admin.ch/publikationen/publikation/00574/index.html?lang=de (www.umwelt-schweiz.ch/div-4002-d)

[6] http://www.bag.admin.ch/themen/chemikalien/00228/00510/05626/index.html

The Conceptual Study is not concerned with the disposal of consumer goods that contain nanomaterials, following their use, since it is not possible at present to stipulate specific disposal measures – should these be necessary – owing to knowledge gaps concerning the type and quantity of such products, and the behaviour of nanomaterials in waste incineration plants, or in other disposal installations.

In addition, materials of nanoscale that arise from technical processes in the form of „by-products“, and are unwanted (ultrafine dust, soot, etc.), are not treated, since these do not arise as a separate waste fraction and are therefore not specifically disposed of.

Nanowaste consists in the main of the following categories:

a. Waste of pure nanoparticles or -rods, NPR.

b. Objects that are contaminated with NPR and are disposed of, such as containers, wiping cloths or disposable protection clothing.

c. Liquid suspensions of NPR that are disposed of as waste.

d. Wastes of solid materials with abradable and thus releasable NPR or with nanostructures that are so loosely applied to the surface, that with handling in the usual way (including disposal), NPR are released or washed off.

3.2. Special nanowastes

In the regulations of the Confederation on the handling of waste (VeVA) [7], special wastes ("Sonderabfälle", roughly corresponding to "hazardous waste" in EU-legislation), , are - freely translated - defined as: „wastes, which owing to their composition, chemical and physical or biological characteristics require, particular comprehensive technical and organizational measures to ensure environmentally sound disposal both in domestic and transboundary movement “.

Nanowastes corresponding to these criteria (see Chapter 3.2.) are designated in this Study as special nanowastes. Fig. 2 shows a classification of nanowastes.

According to the Swiss regulations[8], special wastes must only be passed on to companies that are in possession of an authorization to receive these wastes (Art. 4 VeVA). Furthermore, they must not be mixed with other waste (Art. 5 VeVA). In the absence of suitable control procedures, they must not therefore be disposed of together with household waste or via the disposal routes for commercial waste. Wastes are categorised as special wastes when owing to their quantity, material properties or other characteristics they may impair working safety, the environment or health, or the safe operation of waste installations. Known exam-

[7] Ordinance on the Handling of Waste of 22 June 2005 (VeVA, SR 814.610) and Ordinance relating to the lists concerning the handling of waste of the DETEC of 18 October 2005 (LVA, SR 814.610.1)
http://www.admin.ch/ch/d/sr/c814_610.html
http://www.admin.ch/ch/d/sr/c814_610_1.html

[8] Ordinance on the Handling of Waste of 22 June 2005 (VeVA, SR 814.610) and Ordinance relating to the lists concerning the handling of waste of the DETEC of 18 October 2005 (LVA, SR 814.610.1)
http://www.admin.ch/ch/d/sr/c814_610.html
http://www.admin.ch/ch/d/sr/c814_610_1.html

ples of these are sludges containing heavy metals from the galvanising industry, solvents and distillation residues from the chemical industry, paint and varnish wastes, spent oil, powdery filter residues from waste incineration.

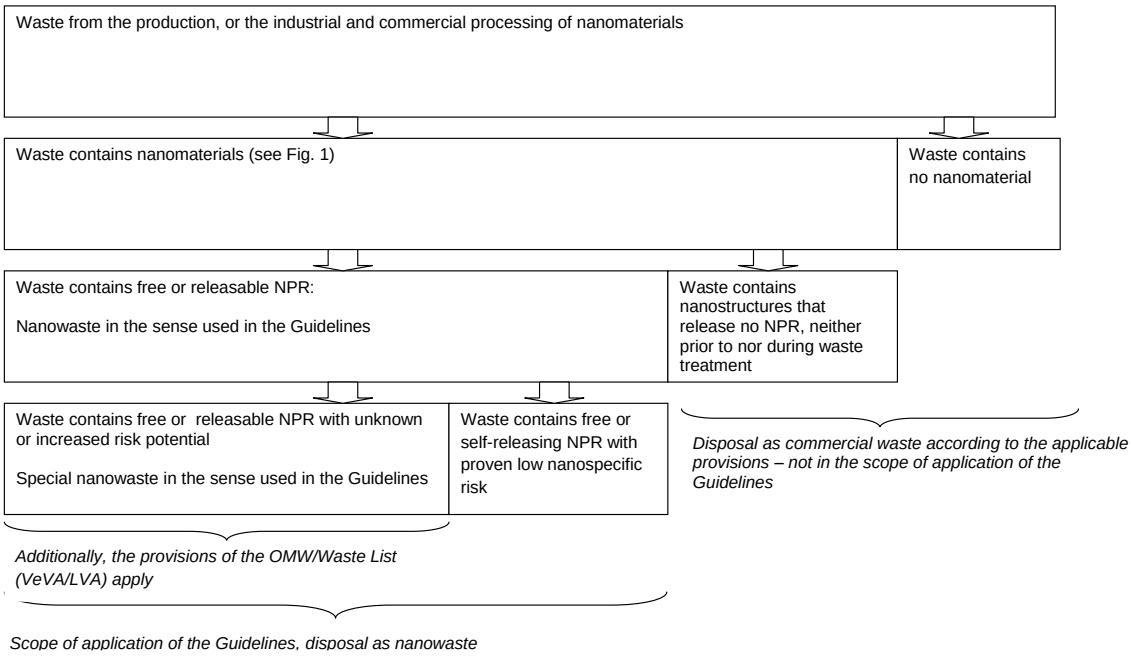

Fig. 2: Scope of application of the Conceptual Study and classification of nanowaste

The provisions of the Federal Council **Ordinance on the Movement of Special wastes VeVA** and the accompanying DETEC **Ordinance relating to the lists for the movement of waste**[9], LVA also apply to nanowastes categorised as special wastes.

Nanowastes from production, and from industrial or commercial processing of nanomaterials are not *a priori* special wastes under VeVA/LVA. However, should one of the following criteria be fulfilled, these wastes are rated as special waste. In consequence, nanowastes with free or releasable nanoparticles or rods are rated as special waste if they:

- either owing to their composition and chemical properties, must be categorised as toxic, hazardous or a hazard to the environment, or
- owing to their nanospecific characteristics, effects on health, safety or the environment cannot be excluded, or the effects are unknown.

The Precautionary Matrix (Chap. 2.3.) gives companies the opportunity to make an initial assessment of the nanospecific need for action, in cases where no other method of categorisation as special waste is known to them. The Precautionary Matrix does not provide a final

[9] Ordinance on the Handling of Waste of 22 June 2005 (VeVA, SR 814.610) and Ordinance relating to the lists concerning the handling of waste of the DETEC of 18 October 2005 (LVA, SR 814.610.1)
http://www.admin.ch/ch/d/sr/c814_610.html
http://www.admin.ch/ch/d/sr/c814_610_1.html

assessment in the sense of a risk assessment. The Matrix is to be filled out and evaluated specifically for disposal, to enable the need for action concerning waste disposal to be assessed. In cases where, for disposal purposes, a nanowaste is categorized in the Precautionary Matrix as Class B („nanospecific need for action exists“), it should be declared as a special waste and disposed of according to the relevant provisions, – unless – based on specific additional investigations - the existence of a potential risk was disproved. The above procedure for rating nanowaste as a special waste should be regarded as a provisional solution, and should be reassessed as soon as a more satisfactory scientific basis is available.

No specific code for nanowastes is contained in the waste list of the LVA. The Working Group therefore proposes that for nanowastes from production, and industrial and commercial processing of synthetic nanomaterials that must be categorised as special wastes and for which, no specific waste code from the waste list of the VeVA/LVA must be used owing to their material characteristics, these should be passed on under one of the following two unspecific VeVA/LVA codes:

16 03 03 S Inorganic wastes containing hazardous substances

16 03 05 S Organic wastes containing hazardous substances

In passing on special wastes in quantities over 50 kg, these must be accompanied by a transport document (Art. 6 VeVA). In each case when special wastes are passed on (not only for quantities over 50 kg, but also for smaller quantities not possessing a transport document), it must be verified that the receiver is provided with information necessary for safe and environmentally sound disposal (e.g. safety data sheet, information required by the Precautionary Matrix , etc.), enabling the receiver to undertake the measures necessary for the handling of nanowastes (Art. 6 Para. 3 VeVA).

Owners may only pass on special wastes to disposal companies in possession of a suitable authorization of the canton (Art. 8 VeVA). The conditions for the acceptance of special nanowastes must be stated in the authorization (cf. criteria in Chapter 4.1 below) (Art. 10 VeVA). Exports of special waste are only permitted with the authorization of the FOEN; an authorization is only issued if it is established that disposal abroad takes place according to standards equivalent to those applying in Switzerland (Art. 15 VeVA).

3.3. General principles for the disposal of nanowastes

Purpose

The disposal of nanowastes must be performed in an environmentally sound manner (Art. 30 Para. 3 LPE).

Pre-treatment of nanowastes inside of companies

Companies which produce or process nanomaterials should take measures leading to a reduction of the waste quantity. The nanowaste arising should if possible be treated directly at the place of occurrence using suitable methods and equipment and in such a way that they lose their nanocharacter (e.g. dissolution of metallic nanomaterials in suitable acid baths, or sintering at high temperatures).

Waste management

Companies that produce or process nanomaterials with free or releasable particles or -rods (NPR) should set up waste management procedures that ensure that the waste arising is collected, documented, packed and passed on for disposal, whereby these working procedures must be carried out at a consistently high standard. The working procedures within the company applying specifically to waste, and the measures required to ensure safety, health and protection of the environment must be recorded, and compliance with them must be assured. The possible sources within the company of nanowaste with free of releasable NPR must be identified and the appropriate safety measures stipulated in handbooks or other documentation.

Reduction of exposure of workers and of emissions to the environment

For each working procedure involving handling of nanowastes with substantial hazard potential or unknown effects, the exposure of workers, the release of nanomaterials (in dust or aerosol form) and emissions to the environment should be kept as low as possible. The exposure is determined from the concentration of the NPR in the air and the duration of the effect. The risk can be reduced by avoiding dust and aerosol development and through short exposure times.

As far as possible, nanowastes should not be collected and passed on in powder form, but in the form of dispersions, pastes, granulates, etc.. In this way, in many cases the hazard potential in subsequent handling (transport, filling of installations, disposal) can be reduced.

3.4. Protection measures under the TOP-principle[10] in handling nanowastes

The protection measures listed below are based on the recommendations of the SUVA on the handling of nanoparticles at the workplace; the conclusions contained in the BAUA/VCI guidelines for working with nanomaterials at the workplace, and on various reports and recommendations from the NanoSafe project (see lists of publications and links in Chapter 5).

Measures at the workplace

In handling nanowastes, the measures below according to the provisional recommendations of the SUVA for handling nanoparticles at the workplace are to be applied.

Technical protection measures

- Use of hermetically sealed apparatus
- Avoidance of generation of dusts and aerosols
- Extraction of dusts and aerosols directly at the source
- Provision for filtering extracted air (HEPA filter H14 when the air is returned to the workroom)
- Where appropriate, isolation of the workroom and appropriate modification of room ventilation (slightly lowered pressure)
- Cleaning of apparatus only by vacuum cleaning with suitable appliances or wiping with a damp cloth, but not by blowing off.

[10] See glossary in the Annex

- For the handling of **combustible nanoparticles**:
  For dispersions in powder form and hazardous powder quantities, explosion protection measures must also be taken. The minimum ignition energies may be reduced for inflammable materials at the nanoscale! The hygienic requirements at the workplace will normally reduce the danger of dust explosion to the inside of hermetically sealed apparatus.
- In handling **nanoparticles with reactive or catalytic effects**:
  Contact with incompatible substances must also be excluded.

Organizational protection measures

- Minimization of the exposure time
- Minimization of the number of persons exposed
- Restriction of access
- Instruction of personnel concerning hazards and protection measures (operational instructions)

Protection measures for individual persons (where the generation of aerosols and/or skin contact cannot be excluded using technical measures)

- Respiratory protection with particle filter P3, protection gloves (with disposable gloves, wearing of two gloves over one-another is recommended)
- Fully closed goggles
- Protection suit with hood (non-woven)
- Instruction on decontamination

3.5. Measures for disposal

In this, all objects belonging to working equipment that may come into contact with NPR must be considered. Thus, for example, sponges or cloths are sometimes used in cleaning operations, which must then be disposed of as nanowaste. Furthermore, scrapers and spatulas are used, which themselves must be cleaned using cleaning cloths and solvents. (according to NanoSafe, Final Report 6.1.5, see Literature)

Nanowastes rated as special wastes may only be disposed of in one of the two following ways: a) taking in return by the supplier in connection with returned goods; b) reception by disposal companies having a corresponding VeVA authorization of the canton (see Chapter 3.2). (Art. 4 in combination with Art. 8 VeVA)

Nanowastes must be collected, placed in temporary storage and documented separately. Mixing with other wastes from the manufacturing or processing works is not permitted (Art. 5 VeVA).

Nanowastes must be packed in such a way that in handling and transport, no NPR can be released. For this, double plastic bags contained in a robust box are recommended. The plastic bags and the box must be marked with the data necessary for the carrier and the disposal company, and especially with the indication that the content in question is nanowaste with free or releasable nanoparticles and rods.

In the transport of nanowastes, ADR/SDR[11] must be complied with.

4. Disposal procedures

In preparing its recommendations on possible disposal procedures for nanowastes, the Working Group had recourse to technical and scientific plausibility considerations. Neither validated nor tested disposal methods for nanowastes are known today.

Nanowastes and special nanowastes must be disposed of in an environmentally sound manner. The measures to be taken for disposal must consider, among others, the characteristics of the substances and be based on the effective risk potential of a waste and on the current status of technology. They cannot be laid down generally in advance.

On passing on nanowastes with free or releasable NPR, it must be ensured that the receiver is given the information necessary for safe and environmentally sound disposal. This serves as one of the basic indications in determining appropriate disposal procedures (e.g. safety data sheet, information according to the Precautionary matrix, transport document in the case of special nanowastes, Art. 6 VeVA).

4.1. Conditioning of the nanowastes, where this is necessary

Whenever possible, nanowastes should be conditioned at their place of occurrence, or if necessary in the disposal company, in such a way that they do not arise in the form of powdery compounds, but as dispersions, pastes, granulates, etc.. In this way, the release of NPR in subsequent waste treatment can be reduced.

The nanowastes must be processed in such a way that in charging waste treatment installations (incineration plants, cement kilns, chemical and physical treatment) the release of NPR is avoided.

4.2. Disposal methods

Basic Principle

The measures for environmentally sound disposal as required by Art. 30 Para. 3 LPE must be suited to the properties of the nanomaterials, and be so performed that, for one, emissions to the environment are kept as low as possible during their treatment and that, for another, the resulting residues do not contain free or releasable NPR. All the provisions of environmental legislation must be complied with. Combustible waste must be incinerated according to Art. 11 TOW.

Disposal in landfills

The provisions of the TOW[12] concerning the disposal of waste in landfills does not take account of any nanospecific properties of waste. The disposal of combustible wastes is explicit-

[11] European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR, SR 0.741.621;); Ordinance concerning the Carriage of Dangerous Goods by Road of 29 November 2002 (SDR, SR 741.621)
[12] Technical Ordinance on Waste of 10 December 1990 (TOW, 814.600)

ly prohibited, which therefore also includes organic nanowastes. In addition, disposal of explosive and infectious wastes, of animal by-products' and wastes that must be treated under the legislation on radiation protection (Art. 32 Para. 2 TOW) is prohibited. No data are available on the behavior of nanowastes in the landfill itself. Further investigations are required to show that by suitable conditioning of the waste, or treatment of the seepage water, NPR cannot be carried over into ground or surface waters. Over and above this, it must be ensured for reasons of environmental protection and protection of workers that, when dumping the wastes, no NPR can be released. In the interim until reliable? results are available, it is recommended that the cantons in granting authorization (according to TOW for landfill authorization, and to VeVA for receiver authorization for special wastes), and also that managers of landfills, should perform a comprehensive evaluation of possible risks.

Disposal of nanowastes in municipal solid waste incineration plants, MSWI

In Switzerland, the waste incineration installations are provided with modern, efficient flue gas scrubbers according to the current status of technology. In the present situation, it can be assumed that nanomaterials that are carried over in small amounts to the MSWI together with consumer goods during domestic waste disposal are either incinerated or removed from the flue gas and disposed of together with the filter residues or scrubber sludge.

It is not, however, recommended to dispose of large quantities of nanowaste or special nanowaste from industry and the trades in the MSWI. Today, too little is known on the behaviour of large concentrations of NPR in the combustion chamber and in flue gas scrubbers of MSWI. Further investigations are required to show whether NPR that are passed on in high concentrations to a MSWI could possibly lead to the emission of NPR to the environment or to hazards in disposing of the slag or filter residues. Until validated results are available, it is recommended that the cantons in issuing authorizations, and also that the operators of MSWI, should perform a thorough investigation of the possible risks.

Other disposal methods for nanowastes

At present, no validated and safe disposal procedures are available for nanowastes. Based on technical and scientific considerations, it can be assumed that the following disposal methods are appropriate to the various classes of nanowaste mentioned. However, for most of the methods listed, further clarification and tests are necessary:

<u>Carbon compounds (e.g. CNT, fullerenes):</u>
Incineration in suitable high-temperature incineration plants, and, if at all necessary, for particular wastes in cement kilns (following suitable conditioning, e.g. dispersion in waste oil and direct introduction to the primary flame). A problem can arise from the high thermal stability of certain synthetic carbon structures (CNT).

<u>Oxides (metal oxides and silicates):</u>
By sintering at raised temperatures, large aggregates that no longer display nanocharacter can be formed.

<u>Metals</u>
Thermal treatment to achieve oxidation, or sintering.
Chemical treatment (dissolution in suitable acids, further treatment of the acid-metal solution).

Special substances

For NPR such as those in semiconductors (quantum dots), organic polymers and NPR with included or adsorbed biological substances (micelles, liposomes, protein particles with elevated hazard potential), incineration in a suitable high-temperature waste incineration plant may be necessary.

Recycling of nanomaterials

From considerations of resource conservation, efforts to recycle and reuse nanomaterials are to be welcomed. To-date, no standard methods or commercial procedures are known to the authors.

4.3. Knowledge gaps and need for research

At present, substantial knowledge gaps exist on questions of the disposal of nanowaste, e.g.:

- Type and quantity of nanomaterials in certain product lines and waste flows (material flow analysis)
- Suitable disposal techniques for certain nanowastes
- Risk of release of NPR from composites during waste treatment (e.g. with shredding)
- Are carbon nanotubes and other carbon structures destroyed during waste incineration?
- How can particular nanomaterials, particularly those with free or releasable NPR, be recycled in a technically, economically and ecologically sound way?

4.4. Requirements for disposal companies concerning special nanowastes

Disposal companies that receive delivery of special nanowaste for disposal must be in possession of a cantonal authorization for this (Art. 8 VeVA). The canton must only issue the authorization if it is ensured that the company fulfils the following requirements (Art. 10 VeVA). In view of the current level of knowledge, it is to be recommended that the authorization authority should make contact with the appropriate instances of the SUVA to ensure that the necessary workplace arrangements, and, if necessary, that the precautionary medical inspections at the workplace are in force. The following requirements relating to environmental protection, safety and health are recommended by the Working Group:

- Special nanowastes must be received separately from other wastes, and processed in a special line specifically for nanowastes in the company, in which they may be registered, prepared, treated and, if applicable, passed on for further processing.
- The company must possess a treatment scheme and a suitable management system for the safe and environmentally sound disposal of nanomaterials, including the provision of quality handbooks and internal works regulations and training programmes for personnel.
- Special nanowastes must only be received and disposed of by a team of co-workers appointed for this purpose and appropriately trained. The team should be kept as small as possible.

- Mixing of special nanowastes with other special wastes is not permitted, except in the case of waste treatment when a specific treatment of the special nanowastes is performed using other wastes (e.g. suspension in waste oil prior to incineration in a high-temperature incineration plant).

- Workplaces at which special nanowastes are handled must be arranged in such a way that dust exposure of the personnel and dust emissions are prevented as far as possible.

- Personal protection equipment must be available for the workers and must be used. The protection equipment must be checked at regular intervals and must be maintained or replaced.

- Regular measurement of the nanoparticle concentration in the room air during work and during stand-by operation.

- The procedures in the case of accidents must be prepared in advance and trained. The responsible emergency services must be informed of the presence of nanowastes, enabling suitable extinguishing methods to be adopted (e.g. spray foam instead of full jet).

4.5. Specific questions to the participants of the practical test for the preliminary version

The inclusion of companies and organizations concerned with the rapidly developing nanotechnologies on a day-to-day basis is of great importance. For this reason, the present Conceptual Study is to be subjected to a practical test intended to answer, among others, the following questions pertaining to the respective company:

- Types and quantities of waste arising in the company?
- Was a comprehensive recording/analysis of nanowaste performed?
- Present-day disposal of nanowastes and resources required for this?
- Seen from the point of view of the companies and organizations – have the most important aspects of waste management been addressed in the Exploratory Study?
- Can the knowledge gaps referred to in the Conceptual Study be filled from the experience of the companies and organizations involved?
- Does the document contain statements that, from the point of view of the companies or organizations addressed, must be described as false?
- In which areas do the companies and organisations lack additional information?
- Is experience available on particular disposal procedures or on the recovery/recycling of nanomaterials?

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5. Annex

5.1. Glossary

FOEN	Federal Office for the Environment 3003 Bern, an office of the DETEC; http://www.bafu.admin.ch/?lang=de
BAG	Federal Office of Public Health 3003 Bern, an office of the Federal Department of Home Affairs (Ministry of the Interior); www.http://www.bag.admin.ch/
BAUA	(German) Federal Institute for Occupational Safety and Health, http://www.baua.de/cln_135/de/Startseite.html
Carbon black	Soot, amorphous, nanoscale, carbon, arising from incomplete incineration processes
cerium	chemical Element, rare-earth metal, atomic number 58, abbreviation, Ce
CNT	Carbon nanotubes, nanoscale carbon tubes, artificially produced carbon structures
DETEC	Federal Department of Environment, Transport, Energy and Communications (Swiss Ministry of the Environment)
exposure	A measure of how strongly an organism is affected by an active agent; dependent, among other things, on the concentration, duration and effectiveness of the substance.
fullerenes	spherical molecules of carbon atoms (e.g. C_{60}), which are variants of the chemical element carbon (in addition to diamond and graphite).
MSWI	Municipal solid waste incineration plant (In Switzerland, this is the equivalent of a KVA or Kehrichtverbrennungsanlage)
KVU	Directors' Conference of the Swiss Cantonal Offices for the Protection of the Environment http://www.kvu.ch/
LVA	(Switzerland) Ordinance relating to the lists concerning the handling of waste of the DETEC of 18 October 2005 (LVA, SR 814.610.1) (Waste List)

nano	prefix designating a size of one billionth (10^{-9})
NanoSafe	A project supported by industry and the universities of the EU for the safe production and use of nanomaterials.
NPR	Nano particles and rods
OMW	Ordinance on Movements of Waste, see VeVA
Quantum Dots	Nanoscale semiconductor structures
to sinter	Thermal coagulation of powdery substances below their melting point
SUVA	Swiss National Insurance Organization, Lucerne http://www.suva.ch/
TOP	TOP principle: basic principle of safety at work, including measures in the order of priority of: Technical, Organisational and Personal protection measures
TOW	Technical Ordinance on Waste, see TVA
TVA	(Switzerland) Technische Verordnung über Abfälle
VCI	German Chemical Industry Association
VeVA	(Switzerland) Ordinance on Movements of Waste
Waste List	Ordinance containing the List of special wastes and other wastes under control, see LVA

5.2. Publications

Swiss Federal Council: Synthetic Nanomaterials Action Plan, Bern, 2008 http://www.bafu.admin.ch/publikationen/publikation/00574/index.html?lang=de

Federal Office for the Environment, FOEN, Federal Office of Public Health, BAG: Synthetische Nanomaterialien -Risikobeurteilung und Risikomanagement. Grundlagenbericht zum Aktionsplan, Bern, 2007;
www.bag.admin.ch/themen/chemikalien/00228/00510/05626/index.html

FOEN/BAG, Precautionary matrix for Synthetic Nanomaterials and Guidelines to the Preparedness Raster, Bern 2008.
http://www.bag.admin.ch/themen/chemikalien/00228/00510/05626/index.html

British Standards Institute BSI : Nanotechnologies – Part 2: Guide to safe handling and disposal of manufactured nanomaterials, PD6699-2, London 2007; http://shop.bsigroup.com/en/Browse-By-Subject/Nanotechnology/Guidance-for-nanotechnology/ (free download - registration required)

BAUA/VCI Leitfaden für Tätigkeiten mit Nanomaterialien am Arbeitsplatz, Frankfurt 2007 ; http://www.baua.de/nn_43190/de/Themen-von-A-Z/Gefahrstoffe/Nanotechnologie/pdf/Leitfaden-Nanomaterialien.pdf

The Royal Society & The Royal Academy of Engineering : Nanoscience and Nanotechnologies, London, July 2004.; http://www.nanotec.org.uk/report/Nano%20report%202004%20fin.pdf

ISO/TC 229: ISO/TS27687, Nanotechnologies – terminology and definitions for nanoparticles, Geneva 2007 (download only at a charge of CHF 180.-) http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_tc_browse.htm?commid=381983&published=on&includesc=true

Nanoinventar, Nanopartikel an Schweizer Arbeitsplätzen; Kaspar Schmid, Brigitta Danuser, and Michael Riediker, Institut universitaire romand de Santé au travail IST, Lausanne 2009 http://www.suva.ch/ist_nanoinventory.pdf (in English; German and French summaries on the Nanotechnology website of the SUVA)

5.3. Links

SUVA Pro, Nanopartikel an Arbeitsplätzen
http://www.suva.ch/home/suvapro/branchenfachthemen/nanopartikel_an_arbeitsplaetzen/

SUVA; Nanotechnologie:
http://www.suva.ch/home/unternehmen/spezialthema/nanotechnologie.htm (This website of the SUVA contains, among other things, the publication “Nanoinventar“ in English and summaries in German and French)

BAG website on nanotechnology:
http://www.bag.admin.ch/themen/chemikalien/00228/00510/index.html?lang=de

FOEN website on nanotechnology:
http://www.bafu.admin.ch/chemikalien/01389/01393/?lang=de

NanoSafe Project:
http://www.nanosafe.org/scripts/home/publigen/content/templates/show.asp?L=EN&P=55&vTicker=alleza

5.4. Case Examples

(It is intended on the basis of the experience gained from the practical test to include one single – or two – examples of concrete applied cases in the final version of the enforcement aid. The project management would welcome any suggestions you may have:)