

PAS 138:2012



BSI Standards Publication

# Disposal of manufacturing process waste containing manufactured nano-objects – Guide

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## Foreword

This Publicly Available Specification (PAS) was commissioned by the Department for Business, Innovation and Skills (BIS) and its development was facilitated by the British Standards Institution (BSI) and came into effect on 01 June 2012.

Acknowledgement is given to the following organizations that were involved in the development of this PAS as members of the Steering Group:

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- HSL;
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Acknowledgment is also given to the members of a wider review panel who were consulted in the development of this PAS.

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This PAS is not to be regarded as a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard.

As a guide, this PAS takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this PAS is expected to be able to justify any course of action that deviates from its recommendations.

### Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

*Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.*

The word "should" is used to express recommendations of this standard. The word "may" is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word "can" is used to express possibility, e.g. a consequence of an action or an event.

### Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

**Compliance with a British Standard cannot confer immunity from legal obligations.**



## Introduction

Despite the promised potential of nanotechnologies to help address societal challenges in almost every area<sup>1)</sup> from energy to healthcare, resource depletion to agricultural production, there are significant concerns over the potential human and environmental health impacts of exposure to manufactured nanomaterials, particularly nano-objects – nanoparticles, nanofibres and nanoplates (DD BS ISO/TS 27687:2009). These concerns are based partly on the premise that manufactured nano-objects are produced to have fundamentally different properties from their larger scale counterparts, hence it is assumed that their behaviour in biological systems will be quite different from that of larger particles with the same composition; and on the assumption, partly supported by research results, that the small size of these objects will allow them to enter cells or cross the blood-brain and placenta barriers, where they will have direct access to vulnerable biological systems. Studies have also indicated that nano-objects with specific composition and morphology can stimulate an early asbestosis-like response in macrophages<sup>2)</sup>, a result which was not altogether unexpected given what was already known about the potential for “long”, straight, insoluble fibres in eliciting such a response, but one that has led to further, unsubstantiated generalizations about hazards of nano-objects.

Whilst the greatest exposure to manufactured nano-objects is expected to occur in occupational settings<sup>3)</sup> the general public will also experience exposure through both deliberate and unwitting use of products containing unbound nano-objects, and from environmental sources resulting from unintentional, accidental or deliberate releases from operations involving the use of manufactured nano-objects. One possible source for environmental exposure may be the inappropriate choice of disposal routes for manufacturing waste.

There is growing evidence of the potential for consumer exposure as it has been reported<sup>4)</sup> that, by March 2011, some 1317 consumer products were claimed by their manufacturers to be nanotechnology based, a number which has shown an almost linear growth rate from 212 in March 2006, when the inventory of products on which these figures are based began. The majority of these products, some 738, come under the category of “health and fitness”, of which 237 are “personal care”, 143 are “cosmetics” and 33 are “sunscreens”, many of which could presumably lead to direct exposure to nano-objects and/or their agglomerates/aggregates through application to the skin. The disposal of these and other nano-object based products and preparations will lead to an increased environmental burden of manufactured nano-objects, which might or might not ultimately provide other pathways for human exposure.

Although the environmental fate and impact of nanomaterials is being intensively studied<sup>5)</sup> there are, as yet, few clear conclusions regarding the environmental behaviour and distribution of this relatively new class of materials. Until such time as we have an improved understanding of this important area, it would seem prudent

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1) See for example Nanotechnology Research Directions: IWGN Workshop Report, National Science and Technology Council Committee on Technology, Interagency Working Group on Nanoscience, Engineering and Technology (IWGN) 1999.  
See [www.wtec.org/loyola/nano/IWGN.Research.Directions/](http://www.wtec.org/loyola/nano/IWGN.Research.Directions/)

2) Craig A Poland, et al, Carbon nanotubes introduced into the abdominal cavity display asbestos-like pathogenic behaviour in a pilot study, *Nature Nanotechnology* 3, 423 – 428 (2008).

3) Nanoscience and Nanotechnologies: Opportunities and Uncertainties, Royal Society and Royal Academy of Engineering, 2004.

4) See [www.nanotechproject.org/inventories/consumer/](http://www.nanotechproject.org/inventories/consumer/)

5) See for example, [www.ennsattox.eu](http://www.ennsattox.eu); [www.nanofate.eu](http://www.nanofate.eu), [www.nanolyse.eu/](http://www.nanolyse.eu/) and [www.nanorettox.eu](http://www.nanorettox.eu)

to try to reduce environmental exposure to waste containing manufactured nano-objects from manufacturing processes by adopting disposal routes that either eliminate or drastically reduce their release to the environment. This document has been developed to provide guidance on this area whilst recognizing that manufactured nano-objects as a class have not yet and perhaps never will be classified as hazardous<sup>6)</sup> and might therefore never be subject to specific control with regards to waste disposal. Like similar guidance in the field [PD 6699-2 and -3 and PAS 130] this document takes a precautionary approach, which is considered appropriate in an emerging field of technology with many uncertainties and a high potential for human and environmental exposure.

In preparing this guidance it was recognized that waste disposal is already subject to significant legislation and regulation, and it is not the intention of this document to lead to an increase in this but rather to provide guidance where none is currently available. It was also recognized that the disposal of post-consumer waste, whilst regulated for certain products, e.g. batteries, low energy and fluorescent light bulbs, is not regulated for the disposal of health and personal care products, such as cosmetics and sunscreens, which appear currently to constitute the largest consumer applications of nanotechnologies. In view of this complex regulatory environment, the disposal of products by consumers is not covered in this PAS. Also excluded from the guidance is the disposal of waste containing naturally occurring and/or incidental nano-objects because of the ubiquity, diversity and nature of such materials.

This PAS does not attempt to address the issue of detecting and identifying manufactured nano-objects in waste, which is covered in a general way in PAS 139. Rather, it relies upon the integrity of all those involved in the production life cycle to maintain appropriate records to allow relevant details on the presence of nano-object constituents, and their concentration/amount, to be passed to companies responsible for disposing of related waste.

## 1 Scope

This Publicly Available Specification (PAS) provides guidance on the safe disposal of manufacturing process waste containing unbound manufactured and/or engineered nano-objects, including agglomerates and aggregates of the same. The guidance given includes good practice for maintaining substance identity of nano-objects in manufacturing processes and associated waste, consideration of nano-object component recovery prior to waste disposal, guidance on appropriate disposal routes, on the preparation of waste materials for transfer to a waste disposal company, and on the information that should be provided to those involved in the disposal of the waste. The document includes a decision tree to assist users in applying its recommendations.

This PAS is intended for use by companies involved in the production, handling or distribution of manufactured and/or engineered nano-objects, those incorporating manufactured and/or engineered nano-objects into products, and those involved in the disposal of relevant waste. It might also be of value to research and development laboratories involved in the preparation, development, use or handling of manufactured or engineered nano-objects, as well as those organizations involved in the regulation and/or monitoring of waste and waste disposal.

Guidance on sampling and analysis of complex matrices, including wastes, for the presence of manufactured and/or engineered nano-objects is given in PAS 139.

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<sup>6)</sup> It is possible that this situation could change during the life of this PAS and users are therefore recommended to check the current situation with the relevant Competent Authority.



This PAS is not intended to provide guidance on the disposal of solid composite materials containing nano-objects that are securely bound within the matrix, post-consumer waste containing nano-objects, or waste containing only naturally occurring and/or incidental nano-objects.

*NOTE 1* Regulating waste is a devolved responsibility in Scotland and Northern Ireland. Where regulation is referred to in this PAS, every effort has been made to identify the relevant regulations for each region of the UK – England and Wales, Scotland, and Northern Ireland. However, as a number of changes to the regulation of waste have occurred over recent years, users of this PAS should ensure that they are conversant with the latest regulations applicable to their situation.

*NOTE 2* Guidance to wider regulations and standards relevant to nanomaterials and nanotechnology-based products is given in PAS 137.

## 2 Terms and definitions

### 2.1 nano-object

material with one, two or three external dimensions in the nanoscale

*NOTE* Generic term for all discrete nanoscale objects.

[DD BS ISO/TS 80004-1:2010, definition 2.5]

### 2.2 nano-scale

size range from approximately 1 nm to 100 nm

*NOTE 1* Properties that are not extrapolations from a larger size will typically, but not exclusively, be exhibited in this size range. For such properties the size limits are considered approximate.

*NOTE 2* The lower limit in this definition (approximately 1 nm) is introduced to avoid single and small groups of atoms from being designated as nano-objects or elements of nanostructures, which might be implied by the absence of a lower limit.

[DD BS ISO/TS 80004-1:2010, definition 2.1]

### 2.3 agglomerate

collection of weakly bound particles or aggregates or mixtures of the two where the resulting external surface area is similar to the sum of the surface areas of the individual components

*NOTE 1* The forces holding an agglomerate together are weak forces, for example van der Waals forces, or simple physical entanglement.

*NOTE 2* Agglomerates are also termed secondary particles and the original source particles are termed primary particles.

[DD BS EN ISO/TS 27687:2009, definition 3.2]

### 2.4 aggregate

particle comprising strongly bonded or fused particles where the resulting external surface area may be significantly smaller than the sum of calculated surface areas of the individual components

*NOTE 1* The forces holding an aggregate together are strong forces, for example covalent bonds, or those resulting from sintering or complex physical entanglement.

*NOTE 2* Aggregates are also termed secondary particles and the original source particles are termed primary particles.

[DD BS EN ISO/TS 27687:2009, definition 3.3]

### 2.5 bound nano-object

nano-object securely contained within a matrix

**2.6 incidental nano-object**

nano-object generated as an unintentional by-product of a process

[Derived from DD BS ISO/TS 80004-1:2010, definition 2.10]

**2.7 flocculate**

<in a liquid> assemblage of particles, which, having been initially dispersed, have become loosely coherent

*NOTE Also referred to as floc.*

[BS 2955:1993, 1.18]

**2.8 ultrafiltration**

use of microporous membranes for the separation of large molecules or very finely divided suspended matter from water by filtration, often by means of applied differential pressure

[ISO 6107-6:2004, definition 100]

**2.9 zeta potential**

electrostatic potential at the slipping plane (which marks the region where liquid molecules surrounding a particle first begin to move with respect to the surface) relative to the potential in the bulk solution

[*Introduction to modern colloid science*<sup>7)</sup>, p22]

**2.10 consignee**

person who receives waste to recover or dispose of it

*NOTE A consignee should have a permit or be exempt from having a permit to accept waste.*

[Environment Agency Guidance – HWR03 Consignment Notes version 1, April 2011<sup>8)</sup>]

**2.11 consignment note**

(in England and Wales) identification form which is required to accompany hazardous waste when it is transferred pursuant to Article 19(2) of the Waste Directive [1]

[The Waste (England and Wales) Regulations 2011 [2]]

(in Scotland) note in a form corresponding to the form set out in Schedule 1 to these Regulations, or in a form substantially to the like effect, and giving at any time the details required by these Regulations to be shown in respect of that consignment (including, where the consignment is one in a succession of consignments, any details required to be shown in respect of other consignments in the succession);

[The Special Waste Regulations 1996 S.I. 1996/972 as amended [3]]

(in Northern Ireland) identification document, as set out in Schedule 4, which is required to accompany the hazardous waste when it is transferred pursuant to Article 19(2) of the Waste Directive;

[The Waste Regulations (Northern Ireland) 2011 No. 127 [4]]

**2.12 consignor**

person who causes waste to be removed from a site

*NOTE 1 This is usually the holder or producer. In some cases (for example, when a managing agent is on site and has authority from the producer or holder), this can be the consignor.*

*NOTE 2 A carrier is not usually a consignor.*

[Environment Agency Guidance – HWR03 Consignment Notes version 1, April 2011<sup>8)</sup>]

<sup>7)</sup> HUNTER R.J. Introduction to modern colloid science. New York:Oxford University Press, 1994.

<sup>8)</sup> Available at [www.environment-agency.gov.uk/business/topics/waste/32196.aspx](http://www.environment-agency.gov.uk/business/topics/waste/32196.aspx)

**2.13 controlled waste**

household, industrial and commercial waste or any such waste

[Environmental Protection Act 1990 [5]<sup>9)</sup> 75(4); The Waste Regulations (Northern Ireland) 2011 [4] 36(a)]

**2.14 duty of care**

responsibility under law of any individual who is the holder of controlled waste to ensure that the waste is managed properly, is recovered or disposed of safely, does not cause harm to human, animal or plant health or pollution of the environment, and is transferred only to someone who is authorized to receive it

[Derived from PAS 100:2011]

**2.15 hazardous waste**

(in England and Wales) waste is a hazardous waste if it is:

- a) listed as a hazardous waste in the List of Wastes;
- b) listed in regulations made under section 62A(1) of the 1990 Act; or
- c) a specific batch of waste which is determined pursuant to Regulation 8 to be a hazardous waste,

[Hazardous Waste (England and Wales) Regulations 2005 as amended [6], Regulation 6]

*NOTE 1 The list of wastes is defined in Regulation 4 of the Hazardous Waste (England and Wales) Regulations 2005 as amended [6].*

*NOTE 2 The 1990 Act means the Environmental Protection Act 1990 [5].*

*NOTE 3 Hazardous waste is referred to as **special waste** in Scotland.*

(in Northern Ireland) waste is a hazardous waste if it is for the time being:

- a) featured in the List of Wastes as a hazardous waste; or
- b) any other waste which (being a waste considered to display one or more of the properties listed in Annex III) is a hazardous waste pursuant to regulation 8; and
- c) a specific waste which, though of a type indicated in the List of Wastes as non-hazardous, is determined pursuant to regulation 9 to be a hazardous waste

[The Hazardous Waste Regulations (Northern Ireland) 2005 No 300 [7], Regulation 6]

*NOTE 4 "The List of Wastes" means the List of Wastes set out in the List of Wastes Decision as it is for the time being set out in the List of Wastes Regulations, being the list referred to in the first indent of Article 1(4) of the Hazardous Waste Directive [8] drawn up on the basis of Annexes I and II, having one or more of the properties listed in Annex III, taking account of the origin and composition of the waste and, where necessary, limit values of concentration (see regulation 5 of [7]).*

*NOTE 5 The other regulations referenced in this definition refer to the above Hazardous Waste Regulations [7].*

*NOTE 6 Includes special waste imported from Scotland within the meaning of the Special Waste Regulations 1996 as amended by the Special Waste Amendment (Scotland) Regulations 2004 [9].*

**2.16 high temperature incineration**

incineration of waste at a temperature in excess of 800° C so as to avoid the creation of dioxins and furans

[Adapted from World Health Organisation Fact sheet N°281, Health-care waste management, October 2011]<sup>10)</sup>

<sup>9)</sup> Available at [www.legislation.gov.uk/ukpga/1990/43](http://www.legislation.gov.uk/ukpga/1990/43)

<sup>10)</sup> Available at [www.who.int/mediacentre/factsheets/fs281/en/index.html](http://www.who.int/mediacentre/factsheets/fs281/en/index.html)

**2.17 landfill**

waste disposal site for the deposit of the waste onto or into land (i.e. underground), including:

- internal waste disposal sites (i.e. landfill where a producer of waste is carrying out its own waste disposal at the place of production); and
- a permanent site (i.e. more than one year) which is used for temporary storage of waste but excluding:
- facilities where waste is unloaded in order to permit its preparation for further transport for recovery, treatment or disposal elsewhere; and
- storage of waste prior to recovery or treatment for a period less than three years as a general rule; or
- storage of waste prior to disposal for a period of less than one year.

*NOTE See Annex A.3, Council Directive 1999/31/EC [2], Article 2.g.*

[BS EN 13965-2:2010, definition 3.29]

**2.18 oxygen plasma ashing**

total removal of organic matter by use of an oxygen plasma

*NOTE Taken from [www.emsdiasum.com/microscopy/products/equipment/plasma\\_asher.aspx](http://www.emsdiasum.com/microscopy/products/equipment/plasma_asher.aspx)*

**2.19 precautionary approach**

management of waste on the basis that lack of scientific evidence of risk should not prevent appropriate precautionary actions being taken

*NOTE Such actions should be proportionate, non-discriminatory, and consistent with previous action, considering both costs and benefits and be subject to review.*

[Adapted from the European Commission, Communication on the Precautionary Principle, 2 February, 2000 – COM (2000) 1 final].

**2.20 proximity principle**

disposal or recovery of waste in one of the nearest appropriate installations, by means of the most appropriate methods and technologies, in order to ensure a high level of protection for the environment and public health

[Adapted from Waste Framework Directive [1], Article 16]

**2.21 recovery**

any of the operations provided for in Annex II of the Waste Framework Directive 2008/98/EC [1].

**2.22 special waste**

any waste which is hazardous waste as defined by Article 1(4) of the Hazardous Waste Directive [8]

[The Special Waste Amendment (Scotland) Regulations 2004 No. 112 [9]]

**2.23 traceability**

ability to identify via records the history of a batch of waste, including identification of all the inputs and related production steps

**2.24 transfer note**

written description of controlled waste transferred in accordance with section 34(1)(c) of the Environmental Protection Act 1990 [5]

[derived from The Waste (England and Wales) Regulations 2011 [2]]

**2.25 waste**

substances or objects which the holder intends or is required to dispose of

[ISO 14040:2006, definition 3.35]

**2.26 waste disposal**

any of the operations provided for in Annex I of the Waste Framework Directive 2008/98/EC [1]

**2.27 waste disposal company**

company permitted to dispose of waste

**2.28 waste management**

collection, transport, recovery and disposal of waste, including the supervision of such operations and aftercare of disposal sites

*NOTE 1 See Annex A.1, Council Directive 91/156/EEC [3], Article 1.d.*

*NOTE 2 Waste management may also include the prevention or reduction of waste generation.*

[BS EN 13965-2:2010, definition 3.56]

**2.29 waste producer**

anyone whose activities produce waste (“original producer”) and/or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste

*Note See Article 3 of the Waste Framework Directive 2008/98/EC [1].*

### 3 Regulatory framework for waste

At the time of writing, there is no regulatory framework in the UK specific to nanomaterials. However, a number of other significant regulatory frameworks apply to this area and due regard should be given to them.

*NOTE 1 Users of this guidance are advised to refer to the latest information available regarding regulations relevant to this field. See, for example, [www.businesslink.gov.uk/bdotg/action/layer?r.s=tl&topicId=1079068363](http://www.businesslink.gov.uk/bdotg/action/layer?r.s=tl&topicId=1079068363)*

Principle amongst these frameworks is the Waste Framework Directive <sup>11)</sup> [1].

This is implemented:

- In England and Wales through the Waste (England and Wales) Regulations 2011 <sup>12)</sup> [2] which came into force on 29 March 2011.
- In Scotland – through the Waste Management Licensing (Scotland) Regulations 2011 SSI 228 <sup>13)</sup> [10] and the Waste (Scotland) Regulations 2011 SSI 226 <sup>14)</sup> [11], both of which came into force on 27th March 2011.
- In Northern Ireland through The Waste Regulations (Northern Ireland) 2011 No. 127 <sup>15)</sup> [4], which, with three exceptions – Regulations 17, 18 and 28, came into force on 8 April 2011. Regulation 17, on duty in relation to the waste hierarchy came into effect on 8 October 2011.

The regulations apply to businesses which produce waste, import or export waste, carry or transport waste, keep or store waste, treat or dispose of waste or which operate as waste brokers or dealers.

If you have waste you have a legal “duty of care”. The duty of care applies to everyone involved in handling the waste, from the person who produces it to the person who finally disposes of or recovers it.

<sup>11)</sup> Available at [www.environment-agency.gov.uk/static/documents/Business/WFD.pdf](http://www.environment-agency.gov.uk/static/documents/Business/WFD.pdf)

<sup>12)</sup> Available at [www.legislation.gov.uk/ukxi/2011/988/contents/made](http://www.legislation.gov.uk/ukxi/2011/988/contents/made)

<sup>13)</sup> Available at [www.legislation.gov.uk/ssi/2011/228/contents/made](http://www.legislation.gov.uk/ssi/2011/228/contents/made)

<sup>14)</sup> Available at [www.legislation.gov.uk/ssi/2011/226/introduction/made](http://www.legislation.gov.uk/ssi/2011/226/introduction/made)

<sup>15)</sup> Available at [www.legislation.gov.uk/nisr/2011/127/contents/made](http://www.legislation.gov.uk/nisr/2011/127/contents/made)

There are some simple rules to follow including keeping waste secure and if you give your waste to someone else (such as a waste contractor) it is your duty to make sure that you check the person is authorized to carry waste. You also need to ensure the waste goes to a proper site (permitted or exempt) and you need to give the person a transfer note or a consignment note, depending on whether the waste is controlled waste or hazardous waste respectively<sup>16)</sup>.

*NOTE 2 Further details of waste management requirements can be found at [www.environment-agency.gov.uk/business/topics/waste/default.aspx](http://www.environment-agency.gov.uk/business/topics/waste/default.aspx)*

## 4 Principles

### 4.1 General

In general terms, all waste, including nano-object containing waste, should be treated in accordance with the waste management hierarchy:

- a) reduction in the amount of waste produced;
- b) reuse of the material;
- c) recovery (for example, recycling);
- d) energy recovery;
- e) disposal.

*NOTE 1 This list is in order of decreasing preference.*

*NOTE 2 The UK Government has produced guidance on the waste hierarchy aimed at waste producers and small business, which can be found at <http://wastehierarchy.wrap.org.uk/> Overarching this, however, should be the overriding principle of sustainability in the wider sense. This takes into account the proximity principle, for example, where this can affect the environmental preference of a particular option.*

Of even greater significance in terms of waste containing manufactured nano objects is the need to manage potential risks posed by the material. Should these be significant or undetermined, this should act as a strong guide towards a disposal route which minimizes exposure risk to people and the environment.

### 4.2 Waste management methods

#### 4.2.1 General

Appropriate methods for the disposal of waste should also take account of the methods of management given in 4.2.2 to 4.2.4.

#### 4.2.2 Segregation

Waste containing manufactured nano-objects should, wherever practical, be segregated from other waste, at least up to the point of disposal or recovery.

#### 4.2.3 Control of releases

Waste containing manufactured nano-objects should be stored prior to disposal or recovery in a manner in which its release to the environment either by natural processes or human intervention is minimized, i.e. it should be kept in weather proof and secure storage.

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<sup>16)</sup> Copies of transfer notes should be kept for a minimum of two years and of consignment notes for a minimum of three years.

#### 4.2.4 Sharing of knowledge

Information relating to any hazardous properties of the material to be disposed of should be passed to anyone else involved in the disposal of that material, for example a waste carrier.

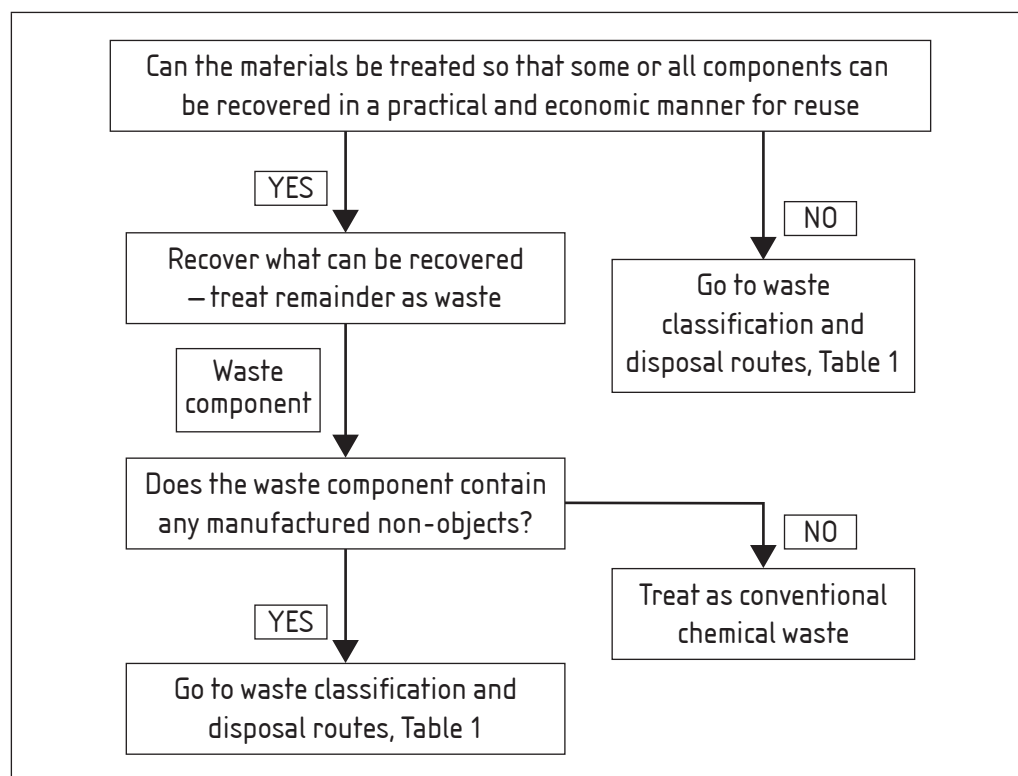
In addition, whilst not a requirement of current legislation, it is strongly recommended that, even where the nano-object component(s) of the waste are not known to present any hazard, the existence, identity and concentration/amount of such nano-object components should be communicated to those involved in waste management of the material in order to support traceability and other elements of a responsible, precautionary approach to such disposal.

## 5 Nano-object containing waste categorization and disposal routes

### 5.1 Decision tree for waste reduction

Prior to classifying post-processing or post-production material not used further for manufacture or incorporation into products as waste, it is recommended that users of this guide review the waste hierarchy and consider opportunities for re-use. The decision tree in Figure 1 provides guidance on this.

Figure 1 Decision tree



### 5.2 General guidance on safe disposal practices

Unless there is evidence that the waste materials do not present any hazards, a precautionary approach to their handling, packaging and disposal should be taken. Waste should be managed in such a manner that exposure to the nano-object component is minimized. It is important that waste materials are handled carefully.

Exposure should be controlled at source by packaging for disposal using appropriate effective local exhaust ventilation (LEV). It is important to match the LEV to the process. LEV should be fitted with High Efficiency Particulate Air (HEPA) filtration. The Health and Safety Executive publish a guidance book<sup>17)</sup> describing the principles and good practice of deciding on, designing, commissioning and testing cost-effective LEV.

Protective clothing, preferably disposable, should be worn if necessary.

*NOTE 3 For example, overalls, boots (without laces), gloves and a suitable filtering face piece (FFP3) dust mask (with a CE mark).*

All employees who use respiratory protective equipment (RPE) should be trained and have had face-fit testing. RPE should be considered as the last resort of protection.

All contaminated items such as filters and disposable PPE should be suitably managed when discarded.

Non-reactive solid waste should be wetted with water possibly including a wetting agent, and kept damp to minimize the release of dust and fibres. In doing so, it is important to remember not to use too much water to avoid run-off entering drains.

Reactive nano-object containing materials should be handled so as to avoid conditions which could promote exothermic reaction or a dust explosion.

When disposing of solid matrices containing nano-objects, lumps should not be broken into smaller pieces to fit into bags or bins. Expelling air from the bag before sealing should be avoided. This might result in the release of nano-objects to the air.

Bags should not be overfilled and sharp objects that could puncture plastic bags should be avoided. Any sharp materials should be wrapped in 1000 gauge polyethylene, or equivalent fit-for-purpose sheeting. If the sheeting is wrapped loosely around the object it is less likely to be punctured. Waste bags should be heavy duty plastic bags and two bags, one inside the other (double bagging) should be used, with the waste being placed in the inner bag. The inner bag should be wiped clean with a dampened cloth or cleaned using a HEPA filtered vacuum cleaner before double bagging, and the outer bag should also be cleaned either by wiping with a dampened cloth or by use of a HEPA filtered vacuum cleaner before removal from the work area. The waste bags should be sealed by twisting the end tightly and then wrapping with duct tape.

Waste liquids containing nano-objects should be stored in sealable containers to prevent any leakage and should also be "double contained". The outside of both inner and outer containers should be wiped clean. The feasibility of separating the nanomaterial from the liquid (e.g. by filtration) before being disposed of should be investigated.

Waste should be packed in UN-approved packaging with appropriate signage. It should be properly labelled and the presence of other chemicals should be identified on the label.

Waste bags and containers should be handled with care and should not be thrown.

Nano-object containing waste should be stored securely to prevent unauthorized access. Once stored, it should be removed and disposed of as soon as practical and economic.

All waste containing manufactured nano-objects should be stored and transported in sealed containers to avoid the generation of aerosols.

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<sup>17)</sup> HSG 258: Controlling airborne contaminants at work.



The transport should be carried out by a registered waste carrier for safe disposal, at a permitted waste management facility<sup>18)</sup>. A waste transfer note or hazardous waste consignment note should be completed, depending on whether the waste is controlled waste or hazardous waste respectively. Copies of these documents should be kept for the minimum period specified in the relevant regulation.

Further options for disposal are considered in 5.3.

### 5.3 Waste categorization and disposal routes

Table 1 provides guidance on categorization of waste containing manufactured nano-objects and disposal of the different categories.

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<sup>18)</sup> It should be noted that sites that produce or hold 500Kg or more of hazardous waste in a year must also register as hazardous waste producers. Further information on premises registration can be found at [www.environment-agency.gov.uk/business/topics/waste/32198.aspx](http://www.environment-agency.gov.uk/business/topics/waste/32198.aspx)

Table 1 Nano-object containing waste categorization and disposal routes

Solid materials		Liquid dispersions		Contaminated wipes, clothing, filters, PPE <sup>a)</sup> , etc
Non-hazardous waste and waste containing dangerous substances in insufficient quantity to classify it as hazardous waste	Hazardous waste and waste containing dangerous substances in sufficient quantity to classify it as hazardous waste			
Water soluble All material types	Water insoluble	All material types	Water-based	Non-water-based
	Carbon based/organic	Other	Amenable to flocculation (report zeta potential)	
Dissolve in excess water and treat as liquid waste in an appropriate manner	Treat by high temperature incineration or oxygen plasma ashing	If sufficient quantities available, or where the dry material presents a fire or explosion hazard, damp to reduce risk of aerosol generation and encapsulate by addition of sand and cement. Dispose of resultant as non-hazardous solid waste	Flocculate, filter, leaving residue damp unless it is known that the dry residue does not present a fire or explosion hazard	For suitable dispersions, treat by high temperature incineration
			Ultrafiltrate, leaving residue damp unless it is known that the dry residue does not present a fire or explosion hazard	
		Double bag/drum, label appropriately and send for disposal as hazardous waste		Double bag, label appropriately and send to landfill as non-hazardous waste unless the type and extent of nano-object contamination cause it to be classified as hazardous

Table 1 Nano-object containing waste categorization and disposal routes (*continued*)

Solid materials	Liquid dispersions			Contaminated wipes, clothing, filters, PPE <sup>a)</sup> , etc
	For small quantities of material not presenting a fire or explosion risk, double bag/drum, label appropriately and send for disposal as non-hazardous waste	Alternatively, and where necessary, e.g. for materials presenting a fire or explosion hazard, encapsulate by damping and incorporating into concrete to diminish environmental mobility, then send for disposal as hazardous waste	Treat residue as solid waste containing nano-objects as appropriate	Where incineration is not appropriate, add excess dispersant, if necessary, to produce a filterable liquid. Ultrafiltrate, leaving residue damp unless it is known that the dry residue does not present a fire or explosion hazard
		If above options are inappropriate because of the hazardous nature of the material, dissolve in appropriate reagent, precipitate hazardous chemical component(s) if feasible. Reuse or send for disposal as hazardous waste.	Treat residue as solid waste containing nano-objects as appropriate	Treat residue as solid waste containing nano-objects as appropriate

Table 1 Nano-object containing waste categorization and disposal routes (continued)

Solid materials	Liquid dispersions	Contaminated wipes, clothing, filters, PPE <sup>a)</sup> , etc
<p>Neutralize remaining liquid and treat as non-hazardous liquid waste. Analyze any non-soluble residue and treat in appropriate manner. Where the hazardous chemical component(s) cannot be precipitated, do not dissolve up but use first option listed</p> <p><i>NOTE Such a procedure might be considered as a process likely to require a permit and therefore users of this guide are advised to discuss any such plans with the relevant Competent Authority (EA, SEPA or NIEA) before proceeding.</i></p>		

Table 1 Nano-object containing waste categorization and disposal routes (*continued*)

Solid materials	Liquid dispersions				Contaminated wipes, clothing, filters, PPE <sup>a)</sup> , etc
<b>Explanatory notes</b>					
Need to check liquid to ensure complete dissolution, e.g. using dynamic light scattering or other suitable method		Only small volumes of such waste is anticipated, e.g. CdSe quantum dots			

a) PPE – personal protective equipment.

## 6 Responsibilities of consignors of waste containing manufactured nano-objects

### 6.1 Duty of care of the waste producer and preparation of waste for submission to waste disposal organizations

There is a legal obligation to comply with the requirements of the waste Duty of Care Regulations<sup>19)</sup> [12]. Whilst these contain no specific mention of nanomaterials, including nano-objects, the regulations require that any waste to be transferred should be fully described and this should include the presence of nano-objects about which there is any uncertainty as to risks they might pose. Where the organization disposing of the waste is not the original manufacturer of the nano-object fraction, the necessary information should be available in the Material Safety Data Sheet (MSDS) provided by the manufacturer. Whilst it is clear that there are frequent inadequacies in the information provided in MSDS, ignorance as to content, or possible hazards posed by a particular waste stream would not be a defence in the event of an accident. Guidance on the completion of Safety Data Sheets for manufactured nanomaterials will be published as ISO TR 13329.

A waste producer has a legal responsibility to ensure that the organization produces, stores, transports and disposes of waste without harming the environment; this is referred to as duty of care.

*NOTE 1 A guide entitled "Duty of care – your waste responsibilities" Crown copyright 2010 has been produced by NetRegs, available at [www.environment-agency.gov.uk/netregs/62529.aspx](http://www.environment-agency.gov.uk/netregs/62529.aspx)*

The guide explains what should be done to comply with the required duty of care for waste [12]. It describes how to store waste safely, who can deal with waste, and the records that should be kept.

The waste duty of care [12] has no time limit. All businesses are specifically responsible for their waste from when it is produced until it has transferred it to an authorized person. If waste is not being managed correctly then appropriate action should be immediately instigated to establish why and to prevent it happening again.

Companies should store and transport their waste appropriately and securely; check that the waste is transported and handled by people or businesses that are authorized to do so; they should complete waste transfer notes or consignment notes to document all waste that is transferred; these records should be kept for at least two years (transfer notes) or three years (consignment notes). Every waste stream, whether hazardous or not, should be accompanied by appropriate documentation: a suitable transfer note for non-hazardous waste or a consignment note for hazardous waste.

*NOTE 2 Users of this guide should ensure that they are aware of and comply with the retention times for these documents.*

Companies should also ensure that anyone who handles the waste has the correct permit, registration or exemption. It is important to check the waste carrier employed is appropriately registered. Any organization which collects and transports waste should be either a registered carrier of controlled waste or exempt from registration. All waste has the potential to pollute the environment if not handled or stored properly.

All waste materials should be safely secured in suitable containers, such as skips, intermediate bulk containers or drums. All waste containers should be kept in good condition and clearly labelled with their contents. It is important to ensure

<sup>19)</sup> Available at [www.legislation.gov.uk/ukxi/1991/2839/contents/made](http://www.legislation.gov.uk/ukxi/1991/2839/contents/made)

that waste cannot blow away. Waste stored in skips or other similar containers should be covered. It is a legal requirement to keep hazardous wastes separated and separate from other types of wastes.

*NOTE 3 Annex A provides some additional background information.*

## 6.2 Hazardous waste and waste presenting a health and safety hazard

*NOTE 1 Under current legislation, waste may only be classified as hazardous waste if it satisfies certain criteria defined in the revised Waste Framework Directive [1]. Such waste has to be disposed of in a specified manner. In addition, the relevant statutory authority may determine in exceptional cases, that a specific batch of waste not satisfying the definition of hazardous waste displays one or more of the hazardous properties, and accordingly that it be treated for all purposes as hazardous waste (see for example, specific waste to be treated as hazardous, Regulation 8 of the Hazardous Waste (England and Wales) Regulations 2005 as amended [6]). However, waste not fulfilling the criteria for designation as hazardous waste might still present a health and safety hazard, which would require that it be treated as "hazardous". There thus exists the enigma that certain wastes, whilst presenting a hazard, can not be classified as hazardous waste and may therefore be disposed of as non-hazardous waste. Having said this, the overriding responsibility of the producer of any waste is covered by the waste Duty of Care Regulations [12], which requires the provision of as much information as someone else might need to handle and dispose of the waste safely.*

Whilst the precautionary approach recommended by this PAS would suggest identifying waste nano-object-based materials as hazardous in cases where there is uncertainty about the hazards presented, the regulatory waste classification of hazardous provides no option for "unknown hazard" or "suspected but unproven hazard". However, as COSHH (see A.3.2) requires that a full risk assessment be performed prior to undertaking work with any material, including its disposal, in cases where there is uncertainty, the results of such a risk assessment should be provided to the consignee of material for disposal. One technique that should be considered in risk assessment is the use of "control banding"<sup>20)</sup>, guidance on the application of this to nanomaterials will be published as ISO TS 12901-2.

Where hazardous waste is to be disposed of, the Hazardous Waste (England and Wales) Regulations 2005 [6] as amended, The Special Waste Regulations 1996 S.I. 1996/972 [3] as amended, and The Waste Regulations (Northern Ireland) 2011 No. 127 [4], require that each consignment be accompanied by a Consignment Note. The information that shall be provided in such Consignment Notes is discussed in the Environment Agency publication "Guidance – HWR03 Consignment Notes"<sup>8)</sup>.

Besides other specified information, Consignment Notes for hazardous waste (special waste in Scotland) should provide a specific classification code or codes for the hazardous properties of the waste, the relevant codes, H1 to H15, being identified in Annex 3 of the Waste Framework Directive [1].

*NOTE 2 Concentration limits (thresholds) apply to the various hazardous properties, these are listed in Article 2 of Commission Decision 2000/532/EC; available at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000D0532:20020101:EN:PDF> (the European Waste Catalogue – EWC).*

Waste is only designated as hazardous if it presents one or more of these hazards at or above the specified concentration, which will have consequences for the disposal route chosen; otherwise it is classified as non-hazardous for disposal purposes.

*NOTE 3 To decide if a waste is hazardous the most appropriate European Waste Catalogue code must be found. Certain codes are always hazardous regardless of concentration of dangerous substances. It is not always specific concentrations that*

<sup>20)</sup> See, for example, [www.safenano.org/KnowledgeBase/Guidance/ControlBanding.aspx](http://www.safenano.org/KnowledgeBase/Guidance/ControlBanding.aspx)

*determine the classification "hazardous", for example the hazardous property "flammable" involves a test to determine if it meets the criteria.*

Further information on the interpretation of the definition and classification of hazardous waste can be found in "Technical Guidance WM2 2011"<sup>21)</sup>. This document provides a helpful hazardous waste assessment framework, which might assist in the classification of any waste where there is uncertainty.

*NOTE 4 For latest information on hazardous waste see [www.environment-agency.gov.uk/business/topics/waste/32180.aspx](http://www.environment-agency.gov.uk/business/topics/waste/32180.aspx)*

*NOTE 5 Details of the standard procedure for completing consignment notes can be found at [www.environment-agency.gov.uk/business/topics/waste/32196.aspx](http://www.environment-agency.gov.uk/business/topics/waste/32196.aspx)*

### **6.3 Non-hazardous waste streams**

Non-hazardous waste means waste which is not classified as hazardous waste.

For non-hazardous waste only, an annual transfer or "Season Ticket" may be used if a number of transfers of the same waste description occur between the same parties. The Nominated Responsible Person should ensure that each segregated waste stream has the appropriate documentation.

Just because a waste is determined not to be hazardous via the EWC (see Note 2 of 6.2) procedure, it does not necessarily mean that there are no significant risks associated with its disposal. The producer should carry out a suitable risk assessment as discussed in 6.2.

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<sup>21)</sup> Available from the Environment Agency at [www.environment-agency.gov.uk/business/topics/waste/32200.aspx](http://www.environment-agency.gov.uk/business/topics/waste/32200.aspx).



**Annex A**  
(informative)**Additional useful background information****A.1 Introduction and background**

It is important that risks associated with health and safety are assessed when disposing of wastes containing nano-objects.

**A.2 Occupational exposure**

Occupational exposure to nano-objects can occur as a result of: incorrect handling, the use of inappropriate, incorrectly fitting, or damaged personal protective equipment (PPE); releases from reactors or as a result of inappropriate or poorly maintained engineering controls; leakage from packaging, waste bags or containers; contaminated bags or containers; as a result of accidental spillage; or during disposal operations.

There are three main routes by which nano-objects can enter the body:

## a) Inhalation.

*NOTE 1 This is considered the primary route of exposure for workers.*

## b) Ingestion:

- By swallowing the mucous that traps and clears particles deposited in the airways;
- By ingestion of contaminated food or water; or
- By oral contact with contaminated surfaces or hands.

## c) Dermal penetration:

- Skin exposure by handling nanoparticles during their packaging or disposal or by contact with contaminated surfaces (from waste bags or containers).

*NOTE 2 It is important to follow safe handling, storage and (typical well-proven) disposal procedures to minimize exposure. See, for example, PD 6699-2:2007.*

**A.3 Safe handling****A.3.1 General**

The general approach towards safe handling and control of nanomaterials is similar to that for other types of materials:

- a) The Control of Substances Hazardous to Health Regulations (COSHH) 2002 [13] outlines a framework to support this;
- b) The REACH Regulation [14], a European regulation concerning the Registration, Evaluation, Authorisation and restriction of Chemicals, covers the full life cycle of chemicals including nanomaterials;
- c) The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) [15] applies to substances that can cause fires and explosions in the workplace, including nanomaterials.

Additionally, PD 6699-2:2007, provides guidance on safe handling and disposal of manufactured nanomaterials and PD 6699-3:2010 provides guidance on assessing airborne exposure in occupational settings relevant to nanomaterials.

### A.3.2 COSHH

The occupational use of materials, including nanomaterials, is regulated under the Control of Substances Hazardous to Health Regulations (COSHH) 2002 (as amended)<sup>22)</sup> [13]. COSHH requires employers to protect workers from exposure to harmful substances in the workplace. Embodying the principles of proportionality and risk assessment, COSHH enables employers to make a valid decision about the measures necessary to prevent or adequately control the exposure of their employees. The regulations can be summarized in an eight-stage approach:

- a) Identify the hazards and assess the risks at all relevant stages;
- b) Decide what precautions are needed;
- c) Prevent or adequately control exposure;
- d) Ensure that control measures are used and maintained;
- e) Monitor the exposure;
- f) Carry out appropriate health surveillance; there is currently no legal requirement for health surveillance for those working with nanomaterials. However, it is good practice to keep records of those working with nanomaterials (e.g. type of nanomaterials, quantities);
- g) Prepare plans and procedures to deal with accidents, incidents and emergencies; and
- h) Ensure employees are properly informed, trained and supervised.

### A.3.3 REACH

REACH is the overarching regulation relevant to chemicals production, importation and use in the European Union<sup>23)</sup>.

REACH applies to all chemical substances, including nanoscale forms. Whilst currently it does not specifically identify nanomaterials, including nano-objects, as distinct forms of a chemical substance, there are ongoing discussions taking place amongst the Competent Authorities of the European Union member states as to how nanomaterials, particularly nano-objects, should be addressed in the regulations. These discussions are supported by three REACH implementation projects on:

- 1) nanomaterials (RIPoN), addressing substance identification (RIPoN 1);
- 2) specific advice on fulfilling information requirements (RIPoN 2); and
- 3) specific advice on exposure assessment and hazard/risk characterization (RIPoN 3) for nanomaterials.

Although final reports for all three projects are available<sup>24)</sup>, it was not possible to reach consensus amongst the experts on the recommendations for project 1.

*NOTE Further work of the Commission, in collaboration with CARACAL<sup>25)</sup>, is required before recommendations on substance identification can be forwarded to the European Chemicals Agency (ECHA).*

### A.3.4 Stability and reactivity

Some nanomaterials, particularly those in nano-object form, might show unusually high reactivity, especially with regards to fire and explosion and in catalytic reaction.

<sup>22)</sup> See <http://www.legislation.gov.uk/ukxi/2004/3386/regulation/2/made>

<sup>23)</sup> See [http://ec.europa.eu/environment/chemicals/reach/reach\\_intro.htm](http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm)

<sup>24)</sup> See <http://ec.europa.eu/environment/chemicals/nanotech/index.htm#ripon>

<sup>25)</sup> See [http://ec.europa.eu/enterprise/sectors/chemicals/reach/caracal/index\\_en.htm](http://ec.europa.eu/enterprise/sectors/chemicals/reach/caracal/index_en.htm)

Due to the chemical and physical properties, particularly the high specific surface area (ratio of surface area to mass) of nano-objects, some nanomaterials can pose a risk of fire and explosion, depending on how they are handled or used. If so, then the principle legislation applying to the control of substances that can cause fires and explosions in the workplace is the Dangerous Substances and Explosive Atmospheres Regulations 2002<sup>26)</sup> (DSEAR) [15].

The key requirements in DSEAR are that risks from dangerous substances are assessed and eliminated or reduced so far as is reasonably practicable. Again the principle of risk assessment applies under these regulations.

#### A.4 Other information and guidance

Guidance on waste is also given in the following:

- Guidance on waste and recovered substances Draft Version 2 (2010)<sup>27)</sup>;
- Guidance on health and safety in the waste management and recycling industries, published by the UK Health and Safety Executive<sup>28)</sup>.

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<sup>26)</sup> See [www.hse.gov.uk/fireandexplosion/dsear.htm](http://www.hse.gov.uk/fireandexplosion/dsear.htm)

<sup>27)</sup> See Guidance on waste and recovered substances [http://echa.europa.eu/documents/10162/13632/waste\\_recovered\\_en.pdf](http://echa.europa.eu/documents/10162/13632/waste_recovered_en.pdf)

<sup>28)</sup> See [www.hse.gov.uk/waste/index.htm](http://www.hse.gov.uk/waste/index.htm)

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PAS 100, *Specification for composted materials*

PAS 130:2007, *Guidance on the labelling of manufactured nanoparticles and products containing manufactured nanoparticles*

PAS 137:2012, *Nanomaterials and nanotechnology-based products – Guide to regulation and standards*

PAS 139, *Guidance on the, detection, characterization and identification of manufactured nano-objects in complex matrices*

BS 2955:1993, *Glossary of terms relating to particle technology*

BS EN 13965-2:2010, *Characterization of waste – Terminology – Part 2: Management related terms and definitions*

PD 6699-2:2007, *Guide to safe handling and disposal of manufactured nanomaterials*

PD 6699-3:2010, *Guide to assessing airborne exposure in occupational settings relevant to nanomaterials*

DD BS EN ISO/TS 27687:2009, *Nanotechnologies – Terminology and definitions for nano-objects – Nano-particle, nanofibre and nanoplate*

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ISO 11074:2005, *Soil quality – Vocabulary*

ISO 14040:2006, *Environmental management – Life cycle assessment – Principles and framework*

ISO TS 12901-2, *Nanotechnologies – Occupational risk management applied to engineered nanomaterials – Part 2: Use of the control banding approach*

ISO TR 13329, *Nanomaterials – Preparation of Material Safety Data Sheet (MSDS)*

### Other publications

- [1] DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives
- [2] STATUTORY INSTRUMENTS 2011 No. 988, ENVIRONMENTAL PROTECTION, ENGLAND AND WALES, The Waste (England and Wales) Regulations 2011, Made 28 March 2011
- [3] STATUTORY INSTRUMENTS 1996 No. 972, ENVIRONMENTAL PROTECTION, The Special Waste Regulations 1996, Made 28 March 1996, as amended by S.I. 1996/2019
- [4] STATUTORY RULES OF NORTHERN IRELAND 2011 No. 127, ENVIRONMENTAL PROTECTION, The Waste Regulations (Northern Ireland) 2011, Made 16 March 2011
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<sup>29)</sup> Amendments are given in The Hazardous Waste (England and Wales) (Amendment) Regulations 2009 available at [www.legislation.gov.uk/ukSI/2009/507/contents/made](http://www.legislation.gov.uk/ukSI/2009/507/contents/made)

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- [10] SCOTTISH STATUTORY INSTRUMENTS 2011 No. 228, ENVIRONMENTAL PROTECTION, Waste Management Licensing (Scotland) Regulations 2011, Made 16 March 2011
- [11] SCOTTISH STATUTORY INSTRUMENTS 2011 No. 226, ENVIRONMENTAL PROTECTION, The Waste (Scotland) Regulations 2011, Made 16 March 2011
- [12] STATUTORY INSTRUMENTS 1991 No. 2839, ENVIRONMENTAL PROTECTION, The Environment Protection (Duty of Care) Regulations 1991, Made 16 December 1991, as amended <sup>30)</sup>
- [13] STATUTORY INSTRUMENTS 2002 No. 2677, HEALTH AND SAFETY, The Control of Substances Hazardous to Health Regulations 2002, Made 24 October 2002, as amended
- [14] REGULATION (EC) No. 1907/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No. 793/93 and Commission Regulation (EC) No. 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC <sup>31)</sup>
- [15] STATUTORY INSTRUMENTS 2002 No. 2776, HEALTH AND SAFETY, The Dangerous Substances and Explosive Atmospheres Regulations 2002, Made 7 November 2002

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<sup>30)</sup> Amendments are given in The Environmental Protection (Duty of Care) (England) (Amendment) Regulations 2003.

<sup>31)</sup> Available at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:396:0001:0849:EN:PDF>





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