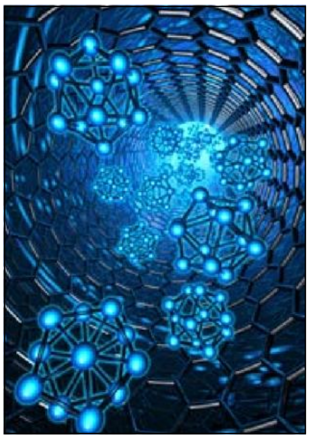
Using nanomaterials at work

Including carbon nanotubes (CNTs) and other biopersistent high aspect ratio nanomaterials (HARNs)



This guidance describes how to control occupational exposure to manufactured nanomaterials in the workplace. It will help you understand what you need to do to comply with the Control of Substances Hazardous to Health Regulations 2002 (COSHH) (as amended) when you work with these substances.

If you work with nanomaterials this guidance will help you protect your employees. If you run a medium-sized or large business, where decisions about controlling hazardous substances are more complex, you may also need professional advice. This guidance will also be useful for trade union and employee health and safety representatives.

This guidance is specifically about the manufacture and manipulation of all manufactured nanomaterials, including carbon nanotubes (CNTs) and other biopersistent high aspect ratio nanomaterials (HARNs). It has been prepared in **HSG272**
response to emerging evidence about the toxicity of these materials. (Published 2013)

Emerging evidence indicates that exposure to some types of nanomaterial can cause inflammation and fibrosis in the lungs or skin inflammation. However, there is insufficient data to confirm the health consequences of long-term repeated exposure and more information is required to properly understand the conditions that produce such effects.

The general control principles described can be applied to all nanomaterials used in the workplace. If using HARNS and other biopersistent nanomaterials, including CNTs, all the general principles described and the extra information highlighted in the labelled boxes should be applied.

Contents

Introduction

1 This guidance describes how to control occupational exposure to manufactured nanomaterials in the workplace. It will help you understand how to comply with the law that deals with the use of these materials at work. The control principles described can be applied to all nanomaterials used in the workplace, any differences in the approach between control of carbon nanotubes (CNTs) and other biopersistent high aspect ratio nanomaterials (HARNs) to any other type of nanomaterials are highlighted in the text. It will help you understand what you need to do to comply with the Control of Substances Hazardous to Health Regulations 2002 (as amended) (COSHH) when you work with these substances.

Who is this guidance for?

2 If you are working with nanomaterials you will need this information to make sure that you are protecting your employees. If you run a medium-sized or large business, where decisions about controlling hazardous substances are more complex, you may also need professional advice – see the 'Getting help' section later on. This guidance will also be useful for trade union and employee health and safety representatives.

Why do I need to read this guidance?

3 This guidance is specifically about the manufacture and manipulation of all manufactured nanomaterials, including CNTs and other biopersistent HARNs. It has been prepared in response to emerging evidence about the toxicity of these materials. It is important that you know what type of nanomaterial you are using. If you are using nanomaterials with the characteristics specified in Box 2, you should follow all of the guidance given in this document and the extra guidance highlighted in the boxes. Note that the additional guidance is mainly in the

controls section. If you are not using nanomaterials with these characteristics then you should follow all the general guidance.

4 This guidance does not deal with incidental release of nanomaterials, such as those from diesel exhaust and welding fumes etc.

5 In addition to inhalation, there is the potential for nanomaterials to come into contact with the skin and gastrointestinal tract because of workplace exposure. With the exception of nanomaterials that are used in cosmetic products, there have been few investigations into the effects of nanomaterials on the skin. Any effects that do arise because of skin contact are expected to be site-specific contact effects. Research into the skin absorption potential of nanomaterials has suggested that if there is any absorption across the skin the amounts that are absorbed will be low.

6 The hazardous properties of engineered nanomaterials are determined by their physical properties, eg size, shape, crystal structure, surface coating, surface reactivity etc and their chemical composition.

7 Not all nanomaterials are hazardous, not all nanomaterials are equally hazardous and there can be considerable variation in toxicity between nanomaterials with a similar chemical composition, because of their physicochemical characteristics.

8 Emerging evidence indicates that when some types of CNTs and other biopersistent HARNs are breathed in they can cause inflammation and fibrosis in the lungs and these effects may be irreversible. However, there is insufficient data to confirm the health consequences of long-term repeated exposure. The type of nanomaterial, its physical form and the presence of impurities and surface modifications may influence the severity of the response but at present there is not enough information to identify all of the factors that are linked with high hazard. It is also not clear if the inhalation of these types of nanomaterials could have a role in the development of other adverse health effects.

9 There is some evidence to suggest that some types of CNTs and HARNs may provoke an inflammatory reaction in the skin, but more information is required to properly understand the conditions of exposure that are required to produce such effects. A summary of what is currently understood about the toxicological properties of nanomaterials is available at: www.hse.gov.uk/nanotechnology/understanding-hazards-nanomaterials.htm.

10 **In view of the evidence for lung damage and lack of information on the effects of long-term repeated exposure, a higher level of control is warranted for CNTs and biopersistent HARNs.**

11 You, as the employer, are responsible for taking effective measures to control exposure and protect the health of your employees and any other person, whether at work or not, who may be affected by the work carried out on your site.

What is a nanomaterial?

12 The term ‘engineered nanomaterials’ is often used to refer to intentionally manufactured nanomaterials. Engineered nanomaterials include a wide variety of different materials and substances, which may present a range of different hazards. One definition of a nanomaterial is a material with at least one dimension in the nanoscale (between 1–100 nm).

13 In 2011 the European Commission adopted the Recommendation on the definition of a nanomaterial.[1] A material that falls within this definition is not automatically hazardous and a material that falls outside this definition is not necessarily of low hazard. If you are unclear about the level of hazard of any material that you are using, you should apply a precautionary approach to risk management.

CNTs and other biopersistent HARNs

Box 1 What are HARNs, including CNTs, and what are the likely health hazards?

HARNs

A particle has a three dimensional shape. Where one or two of these dimensions are much smaller than the others, the particle is said to have a 'high aspect ratio'. Fibres are a classic example. The World Health Organisation (WHO) defines a respirable fibre as an object with length greater than 5 micrometres, a width less than 3 micrometres and a length-to-width ratio (aspect ratio) greater than 3:1. When any of these dimensions is in the nanoscale, a particle that has an aspect ratio greater than 3:1 would be considered a HARN.

Other types of HARNs

Other types of HARNs include nanowires and nanorods. These can be made from a variety of metals and/or other substances. The hazard profile of these HARNs is likely to be influenced by their chemical composition and biopersistence as well as their shape and size. At present there are few experimental hazard data for these nanomaterials and the long-term health consequences of repeated exposure are unknown. In the absence of evidence to the contrary, it should be assumed that biopersistent HARNs have the potential to cause the health effects identified in Box 2.

Plate-like structures (sometimes called nanoplatelets), where only one dimension falls within the nano size range, are also considered to be HARNs. Their aerodynamic behaviour is likely to result in penetration to the deep lung. There is no information to indicate how easily plate-like particles will be cleared from the lungs, but it is possible that their shape and size will prevent effective clearance. In this situation, there is the potential for inflammatory reactions to occur in the deep lung. The long-term health consequences of exposure to plate-like particles are not known. More research is needed into these particle types to understand the level of hazard that they represent.

CNTs

CNTs are an example of a diverse group of HARNs. CNTs are manufactured, three-dimensional forms of carbon, falling into two general groups:

- single-walled (SWCNTs); and
- multi-walled (MWCNTs).

CNTs can differ in terms of chemical composition; they may be pure carbon or contain metals or other materials, by design, through contamination or because of residual catalyst.

Some CNTs exist as long, straight fibres and in the absence of evidence to the contrary, it should be assumed that these types have the potential to cause the health effects identified in Box 2. Other types of CNTs have a more tangled structure and exist as low-density 'fluffy' bundles of nanotubes. No evidence has so far emerged to indicate that these represent a hazard for the pleural cavity.
However, they may still have the potential to cause inflammation in the lungs. It is not possible to make statements about the potential long-term health consequences of repeated exposure to tangled CNTs.

HSE's advice is to take a precautionary risk management approach when there is the potential for workers to inhale CNTs and other biopersistent HARNs with the characteristics identified in Box 2.

CNTs and other biopersistent HARNs

Box 2 Physical characteristics that may indicate high hazard

There is evidence that HARNs with all of the following characteristics:

- are thinner than 3 µm;
- are longer than 10–20 µm;
- are biopersistent;
- do not dissolve/break into shorter fibres;

may be retained within the narrow space surrounding the lungs – the 'pleural cavity' – for long periods. It is known that long fibres that are retained in the pleural cavity can cause persistent inflammation, which may lead to irreversible diseases such as fibrosis and lung cancer.

Legal duties

COSHH

14 The manufacture and use of nanomaterials at work is regulated under the Control of Substances Hazardous to Health Regulations 2002 (as amended) (COSHH).[2]

www.hse.gov.uk/coshh/index.htm

15 COSHH places a duty on employers to carry out a risk assessment for work which is liable to expose employees to hazardous substances. Employers must understand the risks and make sure the risks are kept as low as is reasonably practicable.

DSEAR

16 The chemical and physical properties of some particulate nanomaterials mean that they can give rise to a risk of fire and explosion, depending on how they are handled or used. If this is the case, the principal 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 (DSEAR).[3] www.hse.gov.uk/fireandexplosion/dsear.htm

17 DSEAR requires that risks from dangerous substances are assessed and eliminated or reduced so far as is reasonably practicable.

REACH

18 REACH is a European Union Regulation concerning the Registration, Evaluation, Authorisation and restriction of CHemicals. It came into force on 1 June 2007 and replaces a number of European Directives and Regulations with a single system.

19 REACH will operate alongside COSHH and is designed so that better information on the hazards of chemicals and how to use them safely will be passed down the supply chain by chemical manufacturers and importers through improved safety data sheets.

20 Further information can be found on HSE's website: www.hse.gov.uk/reach/ and on the European Chemical Agency's website: www.echa.europa.eu/home_en.asp.

Establishing hazard

21 To understand the hazards of the materials that you are using, you may think about using information about similar materials. In this case, it is important to make sure that the information you use is truly applicable to the material that you are using for example, CNTs and carbon black.

22 Many of the most commonly-used nanomaterials have similar or the same chemical composition as larger-scale particulates (often referred to as bulk materials). However, it is not clear which properties from a bulk material can be assumed to apply to a nano-sized particulate. In addition, the many differences between nanomaterials means that it is often not clear which properties of a nanosized particulate can be assumed to apply to other nano-sized particulates. It is therefore important to consider 'sameness' when you use information on one material to establish the hazardous properties of another material.

A key step to understanding the hazards of nanomaterials is characterisation

23 To determine the similarities and differences between different nanomaterials, it is important to obtain as much information as possible on the physical and chemical characteristics of each. It is suggested as a minimum that the following characteristics could be used to establish 'sameness':

- chemical composition and purity;
- particle size distribution. You may need to seek specialist advice from the supplier or an expert in the field of nano characterisation to make sure that the particle size distribution information that you are using is suitable for your situation;
- surface functionalisation/treatment;
- shape;
- surface area.

24 The greater the differences between the physical and chemical characteristics of one material and another, even though they may have the same chemical composition, the more likely it is that hazard data for one material will not provide a suitable basis to assess the hazards of another. It is therefore important to have information on the physical and chemical characteristics of the material that you are using, to help you identify materials with similar characteristics that may have similar hazards. If you find hazard data but cannot properly establish the identity and characteristics of the material that has been tested, it is unwise to assume that the results are applicable to your material.

Workplace exposure limits

25 There are currently no UK statutory workplace exposure limits (WELs) specifically for nanomaterials.

26 It should be noted that the UK WEL for carbon black of 3.5 mg/m^3 (3500 micrograms/m^3 is not considered an appropriate WEL for CNTs.

27 Also, the American Conference of Governmental Industrial Hygienists' threshold limit value (ACGIH TLV) for graphite of 2 mg/m^3 respirable dust is not considered an appropriate WEL for graphene.

Assessing risk

28 COSHH requires employers to assess the risk to their employees, and to prevent or adequately control those risks. Sometimes, it is easy to judge the amount of exposure to substances and decide what you can do about it. An example of a suitable COSHH assessment form is available on the HSE nanotechnology website www.hse.gov.uk/nanotechnology/index.htm. You may adapt this form for your organisation.

29 When the task involves very small amounts of nanomaterial and there is little chance of it being released, even if the nanomaterials are harmful, the risk is low. When the task involves larger amounts of nanomaterial, with a high chance of it being released, exposure is higher and so is the risk. For example, during cleaning up and disposal there is the opportunity for direct contact with the nanomaterial and this should be taken into account when deciding what controls are necessary.

Risk assessment

30 A risk assessment is about identifying and taking sensible and proportionate measures to control the risks in your workplace, not about creating huge amounts of paperwork. You are probably already taking steps to protect your employees, but your risk assessment will tell you whether you should be doing more.

31 Concentrate on the real risks – those that are most likely to cause harm. Think about how accidents and ill health could happen and who might be harmed. The following might help:

- Think about your workplace activities, processes and the substances you use.
- Check manufacturers' instructions or data sheets for chemicals and equipment, as they can be very helpful in spelling out the hazards.
- Where are nanomaterials likely to be manufactured/generated/synthesised etc?
- Is exposure likely?
- Who is likely to be exposed?
- Can the exposure be adequately prevented?

- If the exposure cannot be prevented, estimate the potential level of exposures.

32 Having identified the hazards, you then have to decide what to do about them. You don't have to remove all the risks but the law requires you to do everything 'reasonably practicable' to protect people from harm.

Where can exposure occur?

33 Exposure to all nanomaterials at work can occur:

- during and as a result of manufacture;
- during and as a result of incorporation in other materials, eg polymer composites, medical applications and electronics;
- as a result of processes generating nanoparticles in non-enclosed systems;
- during research into their properties and uses;
- when cleaning dust collection systems used to capture nanoparticles;
- as a result of incorrect disposal; and
- as a result of accidental spillage.

34 Work activities involving nanomaterials which require special attention when assessing exposure include:

- weighing, mixing and sieving operations;
- tapping and cleaning operations;
- dissolving operations and spraying-drying operations;
- handling particulate nanomaterials;
- manufacturing nanoparticles (especially production of nanoparticles in a gas phase), and associated maintenance of equipment;
- machining materials containing nanoparticles (eg sawing, polishing, grinding);
- spraying liquids containing nanomaterials;
- processing nanoparticles in a liquid where a high energy output is involved; and
- plant and equipment maintenance.

35 In making the assessment, pay careful attention to the possibility of inhaling particulate nanomaterials.

36 The assessment should be always written down and reviewed if circumstances change or new information becomes available on the hazard of the nanomaterials being used.

Think about each task

37 How might workers be exposed to nanomaterials? By:

- breathing in fumes, mist or dust containing nano-sized particles?

- contact with the skin?
- swallowing?
- contact with the eyes?
- skin puncture?

Bear these in mind when you look at each task.

Myth: 'All carbon nanotubes are the same'

Reality: No! Only some types of carbon nanotubes exhibit the characteristics which cause the greatest concern.

Myth: 'All types of high aspect ratio nanomaterials (HARNs) are harmful.'

Reality: No! A combination of high aspect ratio and bio-persistence causes the greatest concern.

Myth: 'I only work with very small quantities of carbon nanotubes, so I won't be exposed to any!

Reality: It is not just a question of quantities. It is how you use the materials. If it can become airborne, there is a possibility you could be exposed.

Control of risk

38 Nanomaterials are substances of high concern and unless, or until, sound evidence is available on the hazards from inhalation a precautionary approach should be taken to their risk management. If the use or generation cannot be avoided then the implementation of a risk management programme in the workplace can help to minimise the potential for exposure. Elements of such a programme should include the following:

- Assess the worker's job and tasks to determine the potential for exposure.
- Reduce the number of employees handling nanomaterials, and minimise the level and duration of exposure and the quantities used.

39 Where there is a risk of nanomaterials becoming airborne, use the following measures to prevent and control exposure:

- Where possible keep the material wet or damp or use slurries and avoid energetic processes that might generate airborne dusts or aerosols.
- Keep all bottles/vessels containing nanomaterials sealed when not in immediate use. It has been shown that the action of opening vessels can in itself cause nanomaterials to be drawn from the vessel and become airborne.
- Use a damp sheet of absorbent material below the balance when weighing out nanomaterials.

- Use a damp sheet of absorbent material to wipe up spillages of nanomaterials and dispose of as hazardous waste.
- Do not perform tasks on the open bench (see 'What control measures?').

What control measures?

40 Where prevention of exposure to nanomaterials is not reasonably practicable then the duty under COSHH is to control exposure adequately by all routes (inhalation, dermal and ingestion). To help you decide on the most appropriate control measure, follow the nanomaterial control flow chart in Appendix 1.

Engineering control measures

41 Engineering control measures will vary depending on the requirements of each workplace. It may be necessary for those working with nanomaterials to use a combination of methods to control exposure. Total enclosure or partial enclosure/ fume cupboard will be reasonably practicable in many processes involving manufacturing/synthesis or weighing of nanomaterials. Other hood types such as capturing, receiving hoods or down draught benches may be suitable for cutting, sawing, polishing of composite nanomaterials. All local exhaust ventilation (LEV) equipment should be designed and installed to a high standard. For further information see HSG258.[4]

Local exhaust ventilation (LEV)

42 Control exposure at source by carrying out all tasks, including packaging for disposal, in a ducted fume cupboard, or by using other suitable effective LEV. When using other types of LEV, try to enclose the process as much as possible.

43 Ductless HEPA-filtered safety cabinets and recirculating HEPA-filtered microbiological safety cabinets can be used with small quantities (<1 gram) of CNTs, as long as they are subject to rigorous maintenance and checks are carried out to ensure they are effective at all times. See Appendix 2 for more information.

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Box 3 Engineering controls

For use with CNTs and other biopersistent HARNs: the fume cupboard exhaust air should be HEPA filtered (filter class H14), and wherever reasonably practicable vent to a safe place outside. Exhaust air must never be recirculated directly back into the workplace unless it has been effectively filtered to remove airborne nanomaterials by at least one HEPA H14 filter.

Maintenance, examination and testing of control measures

44 Regulation 9 of COSHH requires that every employer who provides any control measure to meet the requirement of regulation 7 must ensure that it is maintained in an effective state, in an efficient working order and in good repair. To comply with regulation 9 you should ensure that:

- All measures used to control exposure to nanomaterials are maintained in good working order and in good repair. (The manufacturer/supplier of plant should be able to help you with appropriate information.)

- A competent person undertakes frequent visual checks and periodically carries out thorough examinations of equipment to ensure they are being maintained adequately. Keep records of all the daily, weekly, monthly and annual LEV checks.
- All LEV plant is examined and tested at least every 14 months (a record of such tests must be kept for at least five years after the date on which they were made).
- Make sure employees are trained in how to check and use the LEV and know who to call if the LEV fails.

Personal protective equipment (PPE)

45 Personal protective equipment (PPE) is often used as part of the control measures implemented. PPE should only be used when all other reasonably practicable measures have been taken, but these have not, in themselves, achieved adequate control. Protective equipment only protects the person wearing it, not anyone else. This also needs checking and maintenance because if it fails it no longer provides protection and exposes the wearer to the hazard. Users need to know exactly how to use and store their PPE correctly as do supervisors.

46 PPE suppliers and trade associations can tell you about training staff in how to use it properly. See the 'Further information'.

Protective clothing

47 When working with nanomaterials, laboratory coats or coveralls made from polyester/cotton or cotton can be used. However, you must make provision for clean overalls/laboratory coats to be put on and dirty ones removed in a manner that does not contaminate individuals or the general workplace. If reusable laboratory coats or overalls are used you must consider their laundering and prevention of secondary exposure. (In the event of a 'one-off' gross contamination, consider treating even 'reusable' PPE as disposable.)

48 How often they need to be changed and laundered will depend on the type of task. As a minimum, it is suggested that laboratory coats should be changed at least once a month. Do not allow work wear to be taken home for laundering.

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Box 4 Protective clothing

For CNTs and other biopersistent HARNs, protective clothing made of materials such as polyethylene textiles (eg Tyvek) performs better than a standard laboratory coat as this type of material does not retain dust or allow dust to penetrate, and can be disposable. Wool, cotton poly-cotton or knitted material, which can retain dust, is not recommended.

Nanomaterials can permeate through some intact disposable overall materials and by implication woven reusable materials (European Nanosafe). Non-woven Tyvek/Tychem polyethylene overalls are recommended for use with nanomaterials, rather than paper or cotton.

Gloves

49 Use suitable disposable single-use gloves manufactured to an appropriate standard. Glove material thickness is a major issue in determining diffusion of nanomaterials and this should be considered in your risk assessment. If your risk assessment indicates latex is the safest choice, then only use low-protein powderfree gloves.

50 Consider other substances used, eg solvents, which may be involved during the nanomaterial handling process. Guidance on choosing the appropriate gloves to protect skin from a variety of substances can be found at www.hse.gov.uk/skin/employ/gloves.htm.

51 Employees should be properly trained in how to put on and remove gloves without contaminating themselves. A training video demonstrating how to remove single-use gloves without contaminating your hands is available at www.hse.gov.uk/skin/videos/gloves/removegloves.htm.

52

CNTs and other biopersistent HARNs

Box 5 Gloves

Use suitable disposable single-use gloves manufactured to an appropriate standard. Glove material thickness is a major issue in determining diffusion of CNTs and other biopersistent HARNs and therefore at least two layers of gloves are recommended to be worn while handling CNTs and other biopersistent HARNs. If your risk assessment indicates latex is the safest choice, then only use low-protein powder-free gloves. Also consider the other materials, eg solvents, which may be involved during the CNT and other biopersistent HARN handling process.

Eye protection

53 Use of suitable eye protection is recommended when handling any chemicals this includes all nanomaterials. A minimum of close fitting safety glasses should be used for all nanomaterials.

Respiratory protective equipment (RPE)

54 There will be situations where other control measures are either not reasonably practicable or fail to achieve adequate control. In these circumstances, the use of respiratory protective equipment (RPE) is a valid control strategy. RPE should only be used when all other reasonably practicable measures have been taken, but these have not, in themselves, achieved adequate control.

55 When choosing RPE it should be suitable and manufactured to an appropriate standard. Also consider any other chemicals, eg solvents, which may be used when handling nanomaterials. Check with your RPE supplier for the most suitable filter.

56 When RPE is used as a secondary control for emergencies or accidental spillages or where additional protection is required as indicated by the risk assessment:

- Disposable and half-masks should have an assigned protection factor (APF) of no less than 20.

57 When RPE is used as a primary control, ie the only method of control (not recommended unless no other method available):

- Use a full-face with mask with APF 40, preferably powered if used for over one hour.

58 All types of masks (including disposable) must be suitable for the task and facefitted for the individual by a competent face-fit tester. Employees should be properly trained in RPE use and supervised. If the equipment is reusable, it should be regularly cleaned and checked to ensure that it remains effective. Written records of RPE maintenance must be kept. For further information on the selection, use and maintenance of RPE see the HSE website www.hse.gov.uk/coshh/basics/ppe.htm.

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Box 6 RPE

HSE recommends that when using HARNs and other biopersistent HARNs including CNTs, RPE with an assigned protection factor (APF) of 40 or higher should be used. If RPE has to be worn for long periods, a powered respirator should be considered.

59 The checklist below is a memory aid to good control practice. To help you decide on the most appropriate control measure, a flow chart is given in Appendix 1 along with adequate control measures. You should use this as an aid rather than a prescriptive tool.

Checklist for control measures

- ☐ Do you design and run your processes to keep the spread of contaminants as low as possible?
- ☐ Do you think about all routes of exposure – breathing in, on skin or swallowing?
- ☐ Do you choose control measures according to the amount of substance, how it gets into the body and how much harm it can cause?
- ☐ Do you make sure that measures are effective, easy to use, and work properly?
- ☐ Do you need to issue PPE?
- ☐ Do you regularly check that measures continue to work, and keep simple records?

- [ ] Do you tell workers about the dangers and how to use control measures properly?
- [ ] Do you avoid increasing the overall health and safety risks when making changes?

Monitoring

60 Monitoring is important to assess whether potential exposure occurs and whether engineering controls are adequate. There is currently no consensus on what is the most appropriate metric or method to measure airborne nanomaterials in the workplace. Sampling strategies based on extensive real-time measurements and offline characterisation of airborne engineered nanoparticles have been described – see www.hse.gov.uk/nanotechnology/forms.htm. Workplace exposure measurement surveys based on extensive monitoring, using a large set of sophisticated equipment, require training and expert knowledge. Currently you should seek expert advice before monitoring for nanomaterials – see www.hse.gov.uk/nanotechnology/when-to-monitor.htm.

Cleaning spillages

61 After use or following a spillage, thoroughly clean the work area and all equipment by wet-wipe cleaning:

- Do NOT brush.
- Do NOT use compressed air for cleaning.
- Do NOT use a standard vacuum cleaner.

62 If a vacuum cleaner is the only reasonably practicable means of cleaning, it must be a dedicated commercial HEPA-filtered cleaner and the filter must be regularly changed under controlled conditions that contain the nanomaterial dust for disposal as hazardous waste. The cleaner itself must only be used for this task and will need to be treated as hazardous waste at the end of its life, following the precautionary approach.

63 Emergency procedures should be in place to deal with spills, accidents and emergencies.

Signage in the workplace for nanomaterials

64 A standardised approach to safety signs for use with nanomaterials does not currently exist, and it is recommended that a diligent approach be taken using, for example, existing risk and safety phrases and warning signs to provide adequate, relevant and specific information on any actual or potential hazards and safety risks.

65 The selection of appropriate hazard labels, signs or pictograms should be based on the available hazard information for the material. In the absence of information, a precautionary approach to signage should be adopted.

Transport of nanomaterials around and outside the workplace

66 Transport nanomaterials in sealed, robust, labelled containers inside secondary containment capable of withstanding foreseeable impacts, eg bottles inside robust plastic outer containers.

Supply of nanomaterials outside the workplace

67 When supplying nanomaterials to another site, health and safety information must be provided with the material. This information should include a warning that the material contains nanomaterials, with an indication of the amount/percentage or concentration. It is also important to bring this guidance document to the attention of the people receiving the nanomaterials. You should also comply with any legal requirements you may have under the Chemicals (Hazard Information and
Packaging for Supply) Regulations 2009 (CHIP).[5]
See www.hse.gov.uk/chip/index.htm and www.hse.gov.uk/ghs/eureg.htm.

Information, instruction and training

68 To comply with regulation 12 of COSHH, employers should give all employees who may be exposed to nanomaterials at work sufficient information, instruction and training to understand the potential risks to their health and the precautions that should be taken to avoid or minimise exposure. Employers should provide adequate supervision, particularly to new and inexperienced workers.

69 The training should detail how control measures are to be used. Employees should be told to report any obvious defects in the control measures to their supervisor.

70 Where RPE is used, you should train your employees to check that it fits properly, and give clear instructions about how to store it and when it should be used, serviced or, if it is disposable, thrown away.

71 Information, instruction and training should, in particular, enable employees to:

- understand the risks to health arising from exposure;
- use the control measures provided effectively;

- use PPE effectively, where necessary;

72 A record of all the information, instruction and training provided should be kept for each employee for as long as they work in the company.

Skills and experience

Competence

73 Ensure that whoever designs, installs, maintains and tests your control measures or performs health surveillance is competent and has the necessary skills. You can assess the competence of equipment and service providers with questions such as:

- Have you done this sort of work before?
- What are your qualifications?
- Do you belong to a professional organisation?
- Can I speak to previous clients?

74 Ideally, you want someone who knows your industry, has a successful record of accomplishment, and gives good value for money.

Worker involvement

75 Involve your workers in developing control measures to make sure they are suitable for the way they carry out the work. Encourage them to suggest improvements, and to report anything they think might be going wrong.

Health surveillance

76 Exposure to nanomaterials does not meet the criteria requiring health surveillance under the COSHH Regulations, since, as yet, there are no tests or health screening method and no links with occupational disease. However, employers should consider putting in place a health monitoring programme. Health monitoring is appropriate where health effects are strongly suspected but cannot be established. For nanomaterials, if a risk assessment for handling the non-nano form requires health surveillance, then health monitoring of work using the nanoform might be appropriate.

77 As a minimum, keep a record of all those working with nanomaterials, via the equivalent of a COSHH health record form, as you would for other substances of concern. See the HSE website for an example of a suitable form and other information on health surveillance and monitoring www.hse.gov.uk/nanotechnology/forms.htm.

Disposal and waste

78 Further information is available from the Scottish Environment Protection Agency (SEPA), the Environmental Agency and the Northern Ireland Environmental Agency (NIEA) websites: www.environment-agency.gov.uk/netregs/businesses/chemicals/112767.aspx

79 Waste nanomaterials classified as 'hazardous waste' must be disposed of in a safe and appropriate manner as described in the British Standard *Guide to the disposal of manufacturing process waste containing manufactured nano-objects* PAS 138:2012.[6]

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Box 7 Disposal

The Environment Agency advises that waste material containing CNT and other biopersistent HARNs should be classified and coded as 'hazardous waste'. In addition, it must be disposed of in a safe and appropriate manner as described by the Environment Agency.[7,8] Based on current information, high-temperature incineration at a hazardous waste incinerator is the preferred disposal method. Other technologies may be suitable if it can be demonstrated that they render the wastes safe.

Getting help

Table 1 Where to get further information on nanomaterials

What and who?	Trade association	HSE website	Consultants/ service suppliers	Local health and safety groups
Good control	4	4	4	4
Testing LEV	4	4	4	4
Training	4	4	4	4
Monitoring		4	4	
Health checks		4	4	

Some useful sources of information

The Occupational Safety and Health Consultants Register (OSHCR)

www.hse.gov.uk/oshcr/index.htm

British Occupational Hygiene Society (BOHS)

5/6 Melbourne Business Court, Millennium Way, Pride Park, Derby, DE24 8LZ
Tel: 01332 298101 www.bohs.org.

BOHS is the professional body for occupational hygienists, who understand how workplace hazards affect worker health and systems to control risks to health from work. The website has a list of consultants.

Safe Nano

IOM Research Avenue North, Riccarton, Edinburgh, EH14 4AP
Tel: 0131 449 8000 www.safenano.org

Safe Nano is based at the Institute of Occupational Medicine (IOM)

Health and Safety Laboratory (HSL)

Business Development Group, Health & Safety laboratory, Harpur Hill, Buxton, Derbyshire SK17 9JN Tel: 01298 218000 www.hsl.gov.uk

HSL's services include specialist advice and consultancy, risk assessment, and workplace monitoring (including biological monitoring).

Institution of Occupational Safety and Health (IOSH)

The Grange, Highfield Drive, Wigston, Leicestershire LE18 1NN Tel: 0116 2573100 www.iosh.co.uk

IOSH is the association for health and safety professionals. The website allows you to search for consultants.

United Kingdom Accreditation Service (UKAS)

21–47 High Street, Feltham, Middlesex TW13 4UN Tel: 02089 178400 www.ukas.com

The UKAS website has a search function to find accredited testing and inspection service providers.

Trade associations

Health and safety information is often produced by trade associations and published in the trade press.

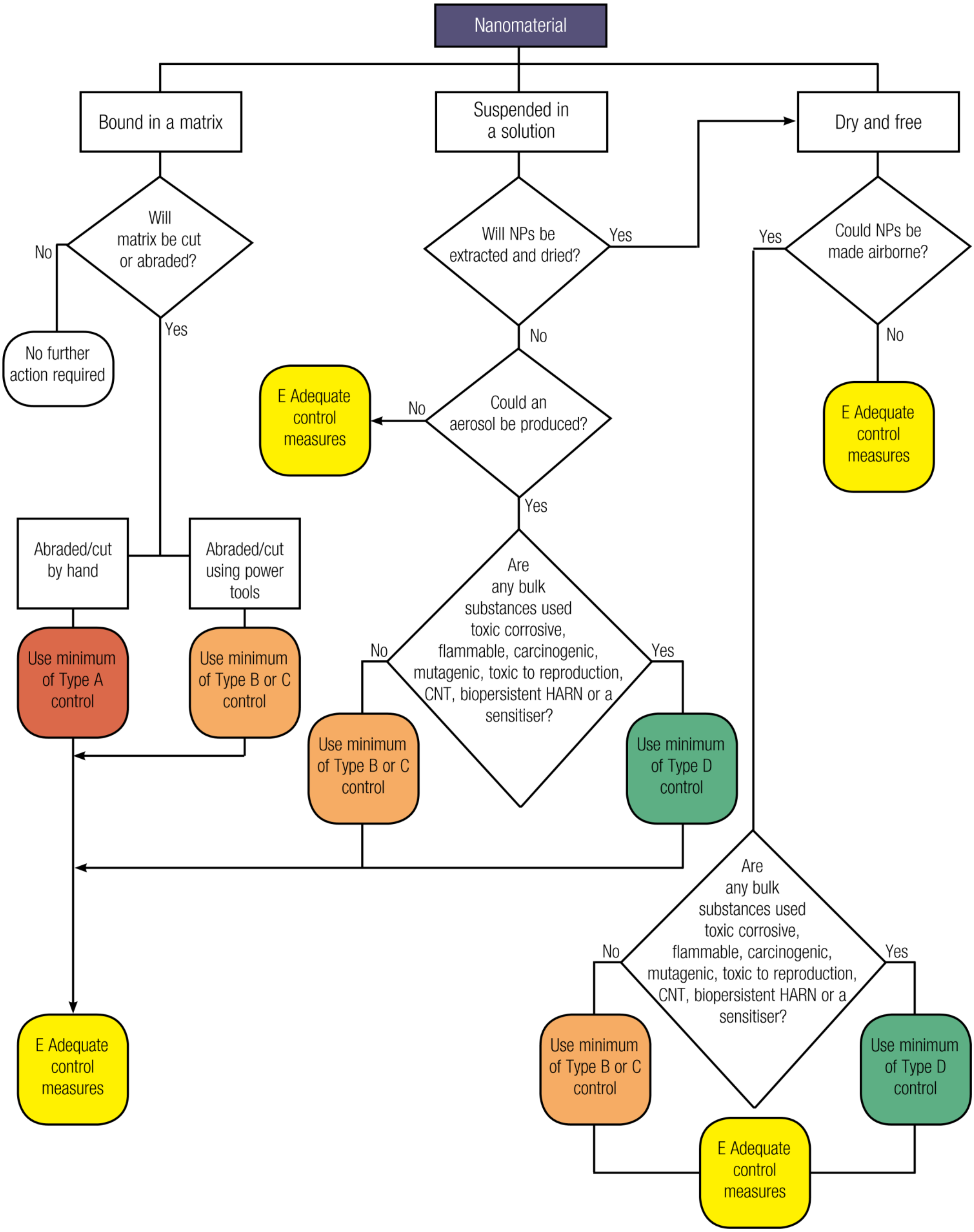
Occupational health professionals (doctors or nurses)

Look in *Yellow Pages* or other trade indexes for occupational health under 'Health and Safety Consultants' or 'Health Authorities and Services', or visit www.nhsplus.nhs.uk.

Safety Groups UK (SGUK)

Edgbaston Park, 353 Bristol Road, Edgbaston, Birmingham B5 7ST
Tel: 0121 248 2011 www.safetygroupsuk.org.uk

Appendix 1 Nanomaterial control flowchart



Key to nanomaterial control flowchart

A Capture hood, or receiving hood, ideally discharged to a safe place outside.
HEPA filtration should be used if exhaust air is to be recirculated back to workplace.

Either:

B partial enclosure, discharged to a safe place outside, eg fume cupboard or well designed bespoke partial enclosure (preferred);

C partial enclosure with HEPA filtration with recirculation to the workplace; or

D full enclosure (enclosed process) with HEPA filtration and discharge to a safe place outside.

Note: HEPA filtration should be used if exhaust air is to be recirculated back into the workplace. Ensure the recirculated air is contaminant free.

E Adequate control measures

1 Minimise the potential to make material airborne.

2 Wear suitable personal protective equipment:

(a) If airborne nanomaterials are not adequately controlled by the engineering control methods (use smoke test to confirm effectiveness of LEV) detailed in the flow chart, then RPE (face masks) will be needed. RPE must be suitable for the task and in accordance with COSHH must be **face-fitted for the individual**. Disposable masks (no less than FFP3 AFP 20 standard) are suitable as a precautionary measure against accidental spillage. Full-face P3 AFP 40 particulate respirators (preferably powered if used for over one hour) would be required for work in an atmosphere containing free airborne nanomaterials.

(b) Overalls or laboratory coats.

(c) Eye protection.

(d) Disposable single use gloves.

(e) Any other PPE, as necessary for the procedure/process being undertaken, such as protective shoes, visors, aprons, hearing protection etc.

3 Regularly clean the work area by wet wiping.

(a) DO NOT use compressed air when cleaning.

(b) DO NOT use brushes on nanoparticle material.

(c) Only HEPA filtered vacuum cleaners may be used with nanomaterials.

4 All control equipment must be subject to regular inspection and annual testing. LEV must undergo a thorough examination and test at least every 14 months as required by COSHH.

5 Dispose of all materials containing free nanomaterials as hazardous waste unless proven non-toxic and environmentally safe.

Appendix 2 Local exhaust ventilation (LEV)

1 Conventional ducted fume cupboards fitted with HEPA filtration and ducted microbiological safety cabinets may be used for CNTs, see below.

Fume cupboards

2 A fume cupboard is an enclosure designed to contain and exhaust vapours and gaseous contaminants generated inside it. A fume cupboard is a key engineering control device, therefore the selection of the appropriate fume cupboard design and following safe work practices are crucial to user safety.

3 For use with CNTs and other biopersistent HARNs the fume cupboard exhaust air should be HEPA filtered, and wherever reasonably practicable vent to a safe place outside.

4 It is important that a fume cupboard complies with BS EN 14175-4:2004[9] and does not lose containment during normal use. In most circumstances, velocity measurements and smoke test will show whether the fume cupboard is effective. Smoke tests can be used to investigate a number of problems, such as:

- irregular airflow and eddy characteristics resulting in air movement out of the cupboard;
- the possible negative effects of equipment on airflow;
- the possible negative effect of heat sources within the cupboard on airflow;
- leakage from the cupboard or ducting.

5 However, if there is any doubt about the integrity of the fume cupboard then it may be necessary to carry out a containment test as in BS EN 14175-4:2004.

6 Installation of fume cupboards must be only be undertaken by those with knowledge of British Standard DD CEN/TS 14175-5:2006 *Fume cupboards. Recommendations for installation and maintenance*.[10] In particular, fume cupboards must not be sited:

- Where they can cause air turbulence and wake affects that can affect the cupboards containment:
  - on heavy pedestrian traffic routes;
  - adjacent to doors;
  - adjacent to opening windows;
- at the open end of a u-shaped laboratory bay, since a fire or explosion within the cupboard may trap workers in the bay.

Note: HEPA filtration should be used if exhaust air is to be recirculated back into the workplace. Ensure the recirculated air is contaminant free.

Microbiological safety cabinets

7 Ducted microbiological safety cabinets can be used. The Class II and III microbiological safety cabinets, unlike the Class I type, provide protection for both the user and the material in the cabinet's working environment. All these cabinets exhaust air through a HEPA filter. (A Class II cabinet is not suitable for handling large quantities of CNTs because it recirculates up to 70% of its air.)

Ductless recirculating HEPA-filtered safety cabinets and recirculating microbiological safety cabinets

8 Safety cabinets and microbiological safety cabinets which recirculate air from the cabinets interior, through a HEPA filter, back into the laboratory can be used for small quantities of CNTs in the absence of hazardous vapours or gases.

9 If using a recirculating safety cabinet or recirculating microbiological safety cabinet the following must be considered:

- Cupboard must conform to British Standard BS 7989:2001.[11]
- The filter must be HEPA; charcoal filters alone must not be used.
- The cupboard should have a filter saturated warning/alarm.
- The cupboard must have a low airflow warning/alarm.
- How is a saturated filter to be safely changed?
- How is the contaminated filter to be safely disposed of? (Incineration?)
- Ensure that the filter integrity test is performed.
- Ensure that the cabinet is subjected to thorough examination and testing at a period not greater than fourteen months, and more frequently if the assessment identifies higher risk, eg every six months.

10 Charcoal filters are designed to absorb vapours and fumes, for which they have a finite capacity. When the capacity is exceeded, contaminate is returned to the workplace. Charcoal filters alone are not designed for filtering solid materials and for these reasons the use of such systems should be avoided.

11 Users should take steps to ensure that the standard of supervision, training, system of work and record keeping is up to date. The safety cabinet should be set aside for use with CNTs or chemically similar materials because some other chemicals may affect the effectiveness and integrity of the fitted filter.

12 HEPA-filtered recirculating cabinets DO NOT absorb or capture fumes, gases or vapours, for which external venting to a safe place would be required in addition to the HEPA filter.

13 HEPA-filter recirculating fume cupboards or cabinets can be used to control any potentially airborne 'dusty' hazardous substance as long as they are subjected to a rigorous risk assessment, BUT should only be considered where external venting to a 'safe place' is not reasonably practicable.

References

1 EU 2011/696/ EU Definition of Nanomaterial http://ec.europa.eu/environment/chemicals/nanotech/pdf/commission_recommendation.pdf

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3 *Dangerous Substances and Explosive Atmospheres. Dangerous Substances and Explosive Atmospheres Regulations 2002. Approved Code of Practice and guidance* L138 HSE Books 2003 ISBN 978 0 7176 2203 0 www.hse.gov.uk/pubns/books/L138.htm

4 *Controlling airborne contaminants at work: A guide to local exhaust ventilation* (LEV) HSG258 (Second edition) HSE Books 2011 ISBN 978 0 7176 6415 3 www.hse.gov.uk/pubns/books/HSG258.htm

5 *CHIP for everyone: Chemicals (Hazard Information and Packaging for Supply) Regulations 2009 (CHIP)* HSG228 (Second edition) HSE Books 2013 ISBN 978 0 7176 6420 7 www.hse.gov.uk/pubns/books/HSG228.htm

6 PAS 138:2012 *Disposal of manufacturing process waste containing manufactured nano-objects. Guide 2012* British Standards Institution

7 *What is a Hazardous waste? A guide to the Hazardous Waste Regulations* EA (2011a) Environment Agency guidance HWR01 (Version 5) 2011

8 *Interpretation of the definition and classification of hazardous waste EA (2011b) Environment Agency Hazardous Waste Technical Guidance* WM2 Revised 2011

9 BS EN 14175-4:2004 *Fume cupboards. On-site test methods* British Standards Institution

10 DD CEN/TS 14175-5:2006 *Fume cupboards. Recommendations for installation and maintenance* British Standards Institution

11 BS 7989:2001 *Specification for recirculatory filtration fume cupboards* British Standards Institution

Find out more

PD ISO/TR 27628:2007 *Workplace atmospheres. Ultrafine, nanoparticle and nanostructured aerosols. Inhalation exposure characterisation and assessment* International Organization for Standardization

DD CEN ISO/TS 27687:2009 *Nanotechnologies. Terminology and definitions for nano-objects. Nanoparticle, nanofibre and nanoplate* International Organization for Standardization

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

PD 6699-3:2010 Nanotechnologies. *Guide to assessing airborne exposure in occupational settings relevant to nanomaterials* British Standards Institution

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Clearing the air: A simple guide to buying and using local exhaust ventilation (LEV) Leaflet INDG408 HSE Books 2008 www.hse.gov.uk/pubns/indg408.htm

EH40/2005 Workplace exposure limits: Containing the list of workplace exposure limits for use with the Control of Substances Hazardous to Health Regulations (as amended) Environmental Hygiene Guidance Note EH40 (Second edition) HSE Books 2011 ISBN 978 0 7176 6446 7 www.hse.gov.uk/pubns/books/EH40.htm

Controlling fire and explosion risks in the workplace: A brief guide to the Dangerous Substances and Explosive Atmospheres Regulations Leaflet INDG370(rev1) HSE Books 2012 www.hse.gov.uk/pubns/indg370.htm

Preventing contact dermatitis at work Leaflet INDG233(rev1) HSE Books 2007 www.hse.gov.uk/pubns/indg233.htm

Read the label: How to find out if chemicals are dangerous Leaflet INDG352(rev1) HSE Books 2010 www.hse.gov.uk/pubns/indg352.htm

Respiratory sensitisers and COSHH: Breathe freely – An employers’ leaflet on preventing occupational asthma Leaflet INDG95(rev2) HSE Books 1995 www.hse.gov.uk/pubns/indg95.htm

Further information

For information about health and safety, or to report inconsistencies or inaccuracies in this guidance, visit www.hse.gov.uk/. You can view HSE guidance online and order priced publications from the website. HSE priced publications are also available from bookshops.

British Standards can be obtained in PDF or hard copy formats from BSI: http://shop.bsigroup.com or by contacting BSI Customer Services for hard copies only Tel: 020 8996 9001 email: cservices@bsigroup.com.

The Stationery Office publications are available from The Stationery Office, PO Box 29, Norwich NR3 1GN Tel: 0870 600 5522 Fax: 0870 600 5533 email: customer. services@tso.co.uk Website: www.tsoshop.co.uk/ (They are also available from bookshops.) Statutory Instruments can be viewed free of charge at www.legislation.gov.uk/.

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