HSE	Field Operation Division SG 6 Occupational Hygiene and Noise and Vibration COSHH and Chemical Carcinogens Unit	**REPORT**

The use of Nanomaterials in UK Universities: an overview of occupational health and safety

Authors:	James Wheeler, Health and Safety Inspector, (Occupational Hygiene) Susan Polak, (COSHH and Chemical Carcinogens Unit)
Date:	January 2013
Distribution:	James Wheeler (FOD SG 6) Susan Polak (COSHH and Chemical Carcinogens Unit) Dr Isla Fairhurst (CSEAD Corporate Science Unit)
For information:	Lydia Harrison (FOD SG 6) Gill Smith (COSHH and Chemical Carcinogens Unit)

1.2 Redgrave Court, Merton Road, Bootle, Merseyside, L20 7HS
Tel: 0151 951 3812 FAX 0151 951 3131

CONTENTS

EXECUTIVE SUMMARY

INTRODUCTION

HSE wishes to increase its knowledge and understanding of the occupational use and manufacture of engineered nanoparticles in the UK. This is required in order to continue to develop a sensible risk-based approach for the regulation of these new technologies so that the UK can fully maximise the benefits. As part of this work, HSE has worked with The UK NanoSafety Group to gain an overview of the work with nanomaterials in a small number of UK universities.

METHODOLOGY

HSE, working with The UK NanoSafety Group, distributed questionnaires in the form of 'feedback' forms to university health and safety officers who, in turn, distributed them to various research groups working with nanomaterials within the universities.

During the summer of 2011 visits were made by a specialist inspector (occupational hygienist) to 9 universities across the UK and within these universities a total of 45 research groups, to see, at first hand, how they were controlling nanomaterials. Seven of the universities visited had returned feedback forms. During these visits the researchers, department heads and health and safety officers were questioned, including using some of the questions from the feedback form to validate the response received. The risk/COSHH assessments and training records were accessed, and the critical controls such as engineering and personal protective equipment (PPE) were examined. Based on reference to HSE guidance and expert opinion, the adequacy of these components of health and safety were assessed for each research group visited.

RESULTS

From the information provided it was found that: the majority of universities using nanotechnology carried out the work in research laboratories within the campus of the universities and not in small 'offshoot' companies; most of the nanotechnology research was being carried out by chemistry and material science departments (this was confirmed during the visits, with chemistry being the dominant discipline); the range and diversity of the nanomaterials used was wide with an estimated 200 different nanomaterials being used.

While a large and diverse range of nanomaterials are used, the quantities used in universities are relatively low. Feedback indicated that the quantities used varied from milligrams a month, to less than 1 kg per month. These values tallied with those found during the visits. Generally the quantities ranged from <10 mg to <10 g and in the majority of research groups the average amount of nanomaterials used was < 1 g. Where nanomaterials were manufactured the quantities were equally small, ranging from 1 g in some departments to up to 1.5 kg in others.

The feedback forms from those who knew from where the nanomaterials were obtained indicated that the majority were manufactured on site (69%), followed by nanomaterials sourced from the UK (38%), imported from Europe (27%) and from the USA (19%).

The feedback showed that the vast majority of universities had been using nanomaterials for over four years, so the use of nanomaterials in universities is not a new concept.

CONCLUSIONS

Overall, the feedback forms and the visits together have provided a good insight into how nanomaterials are being used by some UK universities.

Research groups/university departments are on the whole more than adequately controlling exposure to nanomaterials in laboratories. They are generally following the COSHH hierarchy of control and using management and engineering controls to control exposure, rather than relying on PPE and respiratory protective equipment (RPE).

The move in universities is towards dedicated nanotechnology centres. These centres act as a hub and set the health and safety standard for nanomaterial use within that university. When collaborating with other universities, the researchers from other universities have to follow the same standards otherwise they cannot have access to the centre. Poor standards of health and safety are considered unacceptable by the nanotechnology centres.

In all the universities visited there were usually one or two research groups that achieved a higher than average standard in health and safety and these groups were being used by the university safety officers as exemplars to other groups as to what could be achieved and encouraging them to achieve the same standards. As nanotechnology is a multi-disciplinary subject and collaborations are taking place between research groups/departments and between universities, this is seen as an aid to drive up the standards overall.

However, it was found that some research groups were not achieving adequate standards on some aspects of health and safety. In some cases no general risk or COSHH risk assessments had been carried out, information and training given was poor and the use of engineering controls was inadequate.

1.0 INTRODUCTION

1.1 Nanotechnology involves materials and structures that have at least one dimension of less than 100 nm (a human hair is about 80,000 nm wide). It is a rapidly developing technology, with a wide range of applications across many different industries.

1.2 As with all new technologies, new or unusual risks may arise. Materials in the nano-form may react differently and what we know about their characteristics in the bulk form may not necessarily apply. For example, nanoscale materials may be much stronger or more chemically reactive than their larger forms, or may have different optical, electrical or magnetic behaviours.

1.3 HSE has responsibility for the occupational/worker protection aspect of manufactured nanomaterials and its role is to ensure that people are protected from any risks to health and/or safety arising out of work activities.

1.4 The control of exposure during the occupational use of nanomaterials is principally regulated under the Control of Substances Hazardous to Health Regulations 2002 (as amended) (COSHH). The principles of risk management embedded in COSHH apply to nanomaterials and whilst data gaps exist, the regulatory response is to take a precautionary approach.

1.5 In March 2010 the UK Government launched "UK Nanotechnologies Strategy: Small Technologies, Great Opportunities". In order to fulfil its role in this strategy, HSE needs to increase its knowledge and understanding of the use and manufacture of engineered nanoparticles in the UK, in particular to:

- focus on the numbers of workers who may be occupationally exposed to manufactured nanomaterials and gain a better appreciation of the size of the sectors involved;
- understand the likely routes of occupational exposure to nanomaterials;
- identify the levels of exposure found in workplaces such as factories, research facilities and retail environments; and
- promote good occupational hygiene practice.

2.0 METHODOLOGY

2.1 FEEDBACK FORMS

HSE worked in partnership with The UK NanoSafety Group which was set up by the University Safety and Health Association (USHA) because of concerns raised by university health and safety officers about the use of nanomaterials. The UK NanoSafety Group agreed to administer the distribution of feedback forms to 115 UK universities to seek information on the health and safety arrangements for work with nanomaterials in UK universities. A total of 76 completed forms were received from 19 universities. A copy of the form is at Annex 1.

2.2 FACE TO FACE VISITS

Visits were made to a total of 9 universities across the UK encompassing a total of 45 research groups; 7 of the universities visited had returned feedback forms. HSE assessed the health and safety standards in place at each of the universities by asking questions, examining the records provided, and physically looking at and judging the control measures applied to control nanomaterials in the laboratories.

During these visits the researchers, department heads and health and safety officers were questioned using some of the questions from the feedback form to validate the written responses. The risk/COSHH assessments and training records were assessed, and the critical controls such as engineering and PPE were also examined and assessed. Based on references to HSE guidance and expert opinion, the adequacy of these components of health and safety management was assessed for each research group visited.

During the visits to the research groups at each university an assessment was made on how the research group was controlling and maintaining control of exposures to the nanomaterials. Additionally, what information and training was given, and what records were being kept were also assessed. Four key elements of risk management were assessed:

1. Risk assessment
2. COSHH assessment
3. Information and training
4. Engineering controls

The assessment was made by examining the paperwork provided, asking questions on relevant sections and observing the controls in-situ. On making the assessment the eight principles of COSHH were applied to the judgement and the answers to the following questions were considered:

1. How would you rate the design and operation of the processes and activities to minimise emission, release and spread of nanomaterials?

2. Do you consider that the group has taken into account all relevant routes of exposure (inhalation dermal/ingestion) when developing control measures?
3. Do you consider that the exposure control measures used are proportionate to the health risk?
4. Do you think that the group has chosen the most effective and reliable control options that minimise the escape and spread of nanomaterials and the risk to health?
5. Do you consider that where adequate control of exposure cannot be achieved by engineering controls, suitable other methods of controlling exposure have been used, such as suitable protective equipment?
6. In your opinion does the group check and review regularly all elements of control measures for their continuing effectiveness?
7. Does the group adequately inform and train all employees on the hazards and risks from nanomaterials with which they work, and the use of control measures developed to minimise the risks?
8. Has the group ensured that the introduction of measures to control exposures does not increase the overall risk to health and safety?

The assessment took into account whether the research group was fulfilling the principles of good occupational hygiene practice, following HSE guidance and whether improvements could be made. The following ratings were given to each research group. The ratings were then collated into the tables below to give an overview of performance.

1 = Very Poor
2 = Poor
3 = Satisfactory
4 = Good
5 = Excellent

3.0 GENERAL RESULTS

3.1 ISSUES IDENTIFIED FROM USE OF THE FEEDBACK FORMS

Some universities found the feedback form difficult to complete. The concept of nanomaterials as a single entity created difficulties. At the time the feedback forms were distributed, there was no legal regulatory definition of a nanomaterial and there were roughly four classes of nanomaterials (colloid, quantum dots, wires or fibre) which did not behave the same in a biological context. The structure of the form did not take into account the possibility that a department might be working with more than one class of nanomaterial and did not allow for these to be dealt with separately.

Universities found it difficult to respond appropriately to Section 17 of the feedback form (i.e. number of days using nanomaterials). It is now apparent that the nature of research is such that work takes place as and when necessary, and researchers do not measure their activities in days per week, months or years.

The responses to Section 19, on the estimation of the hazards of nanomaterials, were widely inconsistent. The question set had focused exclusively on fibres and dusts, with the implication that all nanomaterials were small particles, loosely described as dusts and fibres. However a major area of research reported was on nanomaterials in colloids or liquids. Colloids exist only in “solution” where particles are held apart by electrostatic forces. They are either purchased or made in-situ and the particles are rarely isolated. Perturbation of the supporting electrolyte (reducing the volume or the addition of salts etc.) leads to aggregation and the material is no longer ‘nano’. Hence questions 8 and 18, ‘Material form of the nanomaterial’, and ‘Disposal of nanomaterials’, respectively, became slightly contradictory.

As with some of the other Sections, the options for answering Section 20 on control measures were either ‘yes’, ‘no’ or ‘don’t know’. However, containment was not always appropriate or required for the materials in use. Facilities might exist but the action identified might not be relevant to the specific case, so a greater use of open questions allowing the respondent to elaborate may have been more helpful. The feedback forms were filled in by a variety of people from, e.g. heads of department, lecturers, and researchers, and not necessarily the health and safety officer, so there may have been a lack of understanding of some of the health and safety terminology used. The feedback form was designed to be generic and some of the terminology was perhaps more appropriate for industry than universities.

3.2 ADVANTAGES OF USING THE FEEDBACK FORMS

HSE had aimed to produce a generic feedback form to suit both industry and academia and so that the information gathered would be comparable. Although it is now clear that this approach had its limitations, a lot of very useful information has been collected from the feedback forms.

The main advantage of the feedback form is that it provided useful information in the context of universities on:

- the range of nanomaterials being used;
- the physical forms of the nanomaterials in use;
- rough estimates of quantities of all nanomaterials being used; and
- rough estimates of quantities of nanomaterials being manufactured.

We now have a comprehensive list of the types of nanomaterials that are currently being used in UK universities. This information would not have been collected in the short time allowed within a visit as the information is not usually at hand.

The feedback forms give us a ‘snapshot in time’ of the nanomaterials used, how exposures are being controlled, and an approximate figure for the number of people working with nanomaterials in UK universities.

3.3 ISSUES ARISING FROM VISITS

The visits to the universities highlighted the challenges, described above, that the universities experienced when trying to fill in the feedback form, as similar issues were encountered during the visits. One particular difficulty was with identifying the frequency and duration of tasks as this was variable.

Collecting information on the nanomaterials being used by the research group proved to be time-consuming. It was only possible during the visits, to record information on the nanomaterials that were in major use. In hindsight, it would have been preferable to collect this information prior to the visit as each research group might be using a wide range of nanomaterials.

Another area that required a deeper understanding in advance of the visits is the terminology used by universities. Each university is individual and uses slightly different terminology; some had ‘departments’, some ‘disciplines’, and some ‘schools’. Some functions are carried out by estates; others are carried out by the department. This can make it difficult to establish which unit is responsible for the engineering controls and often it is a mixture; estates for some controls and the department for others. Visiting the university had an advantage over the feedback form as it allowed a better understanding of the organisational structure and procedures within the university and the terminology used to describe controls. The visits helped clarify why universities had found the terminology used in the feedback form, and thus its completion, difficult.

3.4 ADVANTAGES OF THE VISITS

Visiting university departments directly allowed a more in depth evaluation of how nanomaterials were being used and controlled, allowing direct questions to be asked and observations to be made.

Talking to the researchers highlighted the complex organisational structures of universities, the diversity and complexity of the research work and reasons why the feedback form caused some difficulty for researchers. It also allowed a greater understanding of the attitudes towards health and safety and further questions on key areas of control could be pursued, which could not be answered from the forms. It also allowed general risk and COSHH assessments to be examined and evaluated and each of the research groups to be rated on their performance.

4.0 STATISTICAL RESULTS AND ANALYSIS

4.1 FEEDBACK FORMS

A total of 76 forms were received from 19 universities across the UK. Feedback forms were sent to all 115 UK universities, with a 17% return rate.

One form was not fully completed because the respondent had felt that the work done in the university was not relevant. Therefore, all data (apart from the first table below) is based on a total of 75 forms received. The responses revealed that nanomaterials were being handled in a range of university departments. Table 1 shows that most nanotechnology research is carried out by the chemistry departments of the universities.

Table 1 University departments

Department	Number	Percentage
Chemistry	20	26%
Biosciences	7	9%
Physics & Astronomy	7	9%
Engineering	5	7%
Environmental Science	5	7%
Materials/Materials Processing	5	7%
Medicine	5	7%
Pharmacy/Pharmacy & Pharmaceutical Sciences/Pharmacy & Biomedical Sciences	5	7%
Chemical Engineering/Chemical Process Engineering	4	5%
Engineering & Electronics	4	5%
Material Sciences	4	5%
Other (Multidisciplinary)	3	4%
Biotechnology	2	3%
TOTAL	**76**	

Q4. Facility type

Respondents were asked to tick all that applied. Table 2 shows the responses. Nearly all of the work with nanomaterials is carried out in research laboratories.

Table 2 **Facility type**

Facility type	Number	Percentage
Research Laboratory	75	97%
Pilot Plant	1	1%
Production Manufacturing	1	1%
Other	0	0%
TOTAL	**77**	

Q5. Location

This question asked for the location as to whether work was carried out off campus or on campus. Table 3, below, shows the responses. Nearly all of the work involved with nanomaterials research is carried out within the universities themselves.

Table 3 **Location**

Location	Number	Percentage
Off Campus	1	1%
On Campus	73	97%
Both	1	1%
TOTAL	**75**	

Q6. Subject classification

Although respondents were invited to tick the box that best classified the subject activities on site, multiple answers were given in many cases. Table 4 below shows the responses. This appeared to be a difficult question for universities to answer as a lot of the nanomaterials research involved more than one department or more than one discipline. Unlike some other research, research on nanomaterials crosses science subject boundaries and breaks with the tradition of single disciplines, so it makes it difficult to assign one piece of research to one discipline. However, the feedback shows that chemistry and material science were the most common disciplines working with nanomaterials and this was confirmed during the visits.

Table 4 **Subject activity**

Subject activity	Number	Percentage
Chemistry	31	41%
Material Science	29	39%
Energy	14	19%
Biological	13	17%
Biotechnology	12	16%
Environmental Science	10	13%
Medicine	10	13%
Pharmaceutical	9	12%
Electrical Engineering	4	5%
Aeronautical Engineering	3	4%
Transportation	3	4%
IT	2	3%
Agriculture	1	1%
Mechanical Engineering	1	1%
Other – Toxicology	1	1%
Blank	2	3%

Summary of questions 7, 8 10 and 11

Q7. Nanomaterials used?

Q8. Physical form of the nanomaterial?

Q10. Rough estimate of quantities of all nanomaterials used per month?

Q11. Rough estimate of quantities of nanomaterials manufactured per month?

Respondents were asked to itemise all the nanomaterials used on site. In terms of the physical form, they were asked to select whether the nanomaterial was a powder, a liquid, a vapour or a mist. They were further asked to give an estimation of the quantities used and an indication of how long the materials had been used. Finally, they were asked to give an estimate of the quantities manufactured and how long they had been manufactured on-site

The list in Annex 2 shows the diverse range of nanomaterials being used by research groups across the UK. From the lists supplied, it is clear that the range and type of nanomaterials used in UK universities is extensive.

Question 10 asked for a rough estimate of the quantities of nanomaterials used. From careful consideration of the feedback forms, the quantities of nanomaterials being used is very variable. Some research groups use milligrams per month, some 1 g per month, and others less than 1 kg per month on average.

Question 11 asked for a rough estimate of the quantities of nanomaterials manufactured. The quantities of manufactured nanomaterials are also very variable, ranging from 1g in some departments to up to 1.5 kg in others.

Q9. Where do you obtain your nanomaterials? (multiple answers)

Respondents were asked to tick all appropriate boxes to indicate where the nanomaterials are being sourced. Table 5 shows the responses. However a high proportion of respondents either did not know the source of their nanomaterials or left the form blank.

Table 5 Nanomaterials sourcing

	Yes	No	Don't know/blank
Manufactured on-site	52 (69%)	5 (7%)	18 (24%)
Sourced in from UK	38 (51%)	2 (3%)	35 (47%)
Sourced in from Europe	19 (25%)	8 (11%)	48 (64%)
Sourced in from USA	19 (25%)	9 (12%)	47 (63%)
Sourced in from China	2 (3%)	13 (17%)	60 (80%)
Sourced in from India		14 (19%)	61 (81%)
Sourced in from Australia	1 (1%)	14 (19%)	60 (80%)
Sourced in from Malaysia		14 (19%)	61 (81%)
Other source *Please specify? Japan, Canada,*	2 (3%)		

Q12. How long has the institution been using nanomaterials?

Respondents were asked for an estimation of the years they had been using nanomaterials. Table 6 shows the responses. The majority of the universities had been using nanomaterials for over four years, so usage was not new to many.

Table 6 Time using nanomaterials

Time in years	< 0.5	1	2	3	4 plus	Blank	Total dept.
	3 (4%)	5 (7%)	10 (13%)	8 (11%)	42 (56%)	7 (9%)	**75**

Q13. People using nanomaterials
Question 13 related to the number of workers using nanomaterials used. Table 7 shows the responses. The Labour Market Statistics classification from the Office of National Statistics was used to group the departments into equivalent industry sizes (www.ons.gov.uk/ons); this indicated that 93% of departments would be classed as small enterprises.

Table 7 Labour Force Classification for number of workers using nanomaterials

Total number of workers	1 to 9	10 to 49	50 to 199	200 to 249	250 plus	Blank	Total Dept.
	55 (73%)	15 (20%)				5 (7%)	**75**

In order to calculate the total number of workers using nanomaterials, the exact numbers of workers were extracted from each of the forms. Table 8 shows the responses. A total of 385 workers were identified (NB the larger numbers are where one form has been used to cover several departments). However, not all feedback forms indicated the number of workers, consequently 385 is an underestimate of the real total number of those working in UK universities.

Table 8 Number of workers using nanomaterials

Number of forms	Numbers of workers	Total
1	32	32
1	28	28
3	17	51
3	14	42
1	13	13
1	12	12
2	10	20
2	9	18
5	8	40
4	6	24
3	5	15
5	4	20
12	3	36
10	2	20
14	1	14
TOTAL 67		**385**

Q14. Gender of workers using nanomaterials

Question 14 asked about the gender of those working with nanomaterials. Table 9 shows the responses. Not all forms indicated the gender or number of workers. Out of the 385 workers identified 62% (239) were male and 38% (146) were female. Only medicine departments had a higher proportion of females to males.

Table 9 Gender of workers using nanomaterials

Department	Number of forms returned	Number of forms used	Number of workers	Number of male workers	Number of female workers
Chemistry	20	19	79	51 (65%)	28 (35%)
Biosciences	7	7	25	14 (56%)	11 (44%)
Physics & Astronomy	7	7	65	49 (75%)	16 (25%)
Engineering	5	4	7	4 (57%)	3 (43%)
Environmental Science	5	4	38	21 (55%)	17 (45%)
Materials/Materials Processing	5	5	29	21 (72%)	8 (28%)
Medicine	5	4	25	10 (40%)	15 (60%)
Pharmacy/Pharmacy & Pharmaceutical Sciences/Pharmacy & Biomedical Sciences	5	4	20	11 (55%)	9 (45%)
Chemical Engineering/Chemical Process Engineering	4	4	27	19 (70%)	8 (30%)
Engineering & Electronics	4	2	4	4 (100%)	0 (0%)
Material Sciences	4	3	9	7 (78%)	2 (22%)
Other (Multidisciplinary)	3	2	49	26 (53%)	23 (47%)
Biotechnology	2	2	8	2 (25%)	6 (75%)
TOTAL	**76**	**67 (88%)**	**385**	**239 (62%)**	**146 (38%)**

Q15. Age range of workers using nanomaterials

Question 15 asked about the age range of the workers using nanomaterials. Table 10 shows the responses. Only 51 forms were able to be used to identify the age ranges of those using nanomaterials. 70% of the 283 workers whose age was reported were in the 22 to 31 age range. This was expected for a relatively new and growing topic such as work with nanomaterials and for university populations in general.

Table 10 Age range of workers using nanomaterials

Department	Number of forms returned	Number of forms used	18 – 21	22 – 31	32 - 41	42 - 51	52+	Total
Chemistry	20	16		50	5	3		58
Biosciences	7	6	3	14	3	1		21
Physics & Astronomy	7	7		42	14	9		65
Engineering	5	4	1	5	1			7
Environmental Science	5	4		22	12	2	2	38
Materials/Materials Processing	5	3	2	8			1	11
Medicine	5	1		10	4			14
Pharmacy/Pharmacy & Pharmaceutical Sciences/Pharmacy & Biomedical Sciences	5	1			1			1
Chemical Engineering/Chemical Process Engineering	4	3	5	4	1			10
Engineering & Electronics	4	1		2			2	4
Material Sciences	4	3		3		2		5
Other (Multidisciplinary)	3	2		39	7	3		49
Biotechnology	2	0						0
Totals	**76**	**51 (67%)**	**11 (4%)**	**199 (70%)**	**48 (17%)**	**20 (7%)**	**5 (2%)**	**283**

Q16. Average daily time spent using nanomaterials

Question 16 looked at the time spent working with nanomaterials. Table 11 shows the responses.

The frequency with which nanomaterials were used was variable. In general, 62% of the workers spent <3 hours per day working with the nanomaterials.

This was considered to be a difficult question; the research groups visited indicated that this varied and could be once a week, once every two weeks, once a month or once a year. Individual tasks took from 10 minutes to 30 minutes to a couple of hours; however it is not usual for universities to record this information.

Table 11 Time spent working with nanomaterials in hours

Time spent in hours per day	1	2	3	4	5	6 plus	Blank	Total dept.
	22 (29%)	15 (20%)	10 (13%)	12 (16%)	2 (3%)	6 (8%)	8 (11%)	**75**

Q17. Average numbers of days per week using nanomaterials

Question 17 considered the number of days per week spent working with nanomaterials. Table 12 shows the responses.

The average number of days per week using nanomaterials was fairly evenly distributed. This was also a difficult question for the universities to answer as the very nature of research is difficult to quantify in terms of time. A project may last three years and the work will take place when necessary. It is not as regular or predictable as might be expected in other industry sectors.

For example, it can take 1 to 3 months for some research groups to use the small quantities of nanomaterials and between 3 and 120 months for other groups.

Where research groups are manufacturing nanomaterials; some manufacture continuously, whilst other groups do this in batches every couple of months.

Table 12 Time spent working with nanomaterials in days

Days per week	1	2	3	4	5	6	7	Blank	Total dept.
	11 (15%)	13 (17%)	16 (21%)	8 (11%)	20 (27%)			7 (9%)	**75**

Q18. Disposal of nanomaterials (multiple answers)

Question 18 considered how nanomaterials were treated in terms of disposal of waste materials. Table 13 shows the responses.

43% of departments treated nanomaterials as specialist waste. 27% of the departments used them up completely during the process and produced no waste. Where respondents ticked ‘other’ as the disposal route there were generally four ways the disposal took place:

- sending waste back to the manufacturer;
- recycling waste (particularly for the precious metals);
- no disposal (keep nanomaterial in-house as a record); and
- washing the waste down the sink (e.g. small slurries of magnetite washed down sink with excess water).

Table 13 Disposal of nanomaterials

Number	Type of waste
20 (27%)	No waste (all nanomaterial used)
32 (43%)	Specialist waste
11 (15%)	Landfill
6 (8%)	Incineration
7 (9%)	Blank
12 (16%)	Other
75	**Total dept.**

Q19. In your opinion do you think nanomaterials present a health risk?

Question 19 was a question intended to find out how the health risks of nanomaterials were perceived. Table 14 shows the responses.

It was apparent that this was also a difficult question for respondents to answer. However a sample of the responses has been presented in Annex 3, broken down by departments, and gives a good indication of views and perceptions.

The responses to this question quite understandably were dependent on the type of nanomaterial being used. However, the overall perception was that they had not been tested extensively and therefore a health risk might be present.

Table 14 Perception of the health risk

Health risk	Yes	No	Don't know	Blank	Total dept.
	27 (36%)	28 (37%)	11 (15%)	9 (12%)	**75**

Q20. Types of controls?

Question 20 asked a few questions on types of controls used. Table 12 shows the responses.
64% of departments used management of people and activities to control and reduce the exposure of nanomaterials. The information gained from the visits showed that this was done by mainly restricting access to laboratories and only allowing certain people to handle nanomaterials.

Engineering controls were used by 72% of the departments. Equal proportions (39%) said they were or were not using respiratory protection. Gloves were worn in 92% of cases.

53% said that they used protective clothing. This may be a result of the terminology used not being common in the university environment and would therefore account for the number of forms left blank.

Overall, it was encouraging to see that the university departments appear to be following the COSHH hierarchy of control and that engineering controls and management controls were used in preference to RPE/PPE to control workers exposure to nanomaterials.

Table 15 Types of controls used to reduce nanomaterials exposure

Type of controls	Yes	No	Don't know	Blank	Total dept.
MANAGEMENT OF PEOPLE AND ACTIVITIES (i.e. restricted access)	48 (64%)	12 (16%)	4 (5%)	11 (15%)	**75**
ENGINEERING (i.e. Fume cupboard +HEPA filter; Open-fronted spray booth; Downdraught booths)	54 (72%)	12 (16%)		9 (12%)	**75**
RESPIRATORY PROTECTION (i.e. Disposable masks, air fed etc)	29 (39%)	29 (39%)	2 (3%)	15 (20%)	**75**
GLOVE (i.e. Disposable)	69 (92%)	1 (1%)		5 (7%)	**75**
PROTECTIVE CLOTHING (i.e. Tyvek suits)	40 (53%)	21 (28%)		14 (19%)	**75**

Q20. In your opinion what is the main route(s) of exposure for the nanomaterials used on site?

Question 20 is a question to ascertain information on the perceptions on the route of exposure for the nanomaterials. Table 16 shows the responses. 52% believed that the main route of exposure was dermal and 37% thought it to be inhalation. This is significant as it can much easier to control dermal exposure than inhalation and this links to the high level of glove usage reported above. This perception was verified during the visits, as the drive in the universities was to use the nanomaterials in solution as they were easier to control and manipulate. It was also observed that those universities that had to use dry powdered nanomaterials always tried to use the least dusty form.

Table 16 Routes of exposure for nanomaterials

Route	Yes	No	Don't Know	Blank	Total Dept
Inhalation	28 (37%)	22 (29%)	2 (3%)	23 (31%)	**75**
Dermal	39 (52%)	17 (23%)	2 (3%)	17 (23%)	**75**
Ingestion	4 (5%)	32 (43%)	2 (3%)	37 (49%)	**75**
Injection	1 (1%)	29 (39%)	3 (4%)	42 (56%)	**75**

Q21. Information available

Question 21 asked questions on the type of information that universities considered they should keep on record. Table 17 shows the responses.

A few questions were asked on information that should be available in the laboratory. However, quite a number of forms were left blank. This may indicate that the terminology used was confusing and not understood by the departments.

88% of the departments had kept records of their COSHH risk assessment but only 12% were keeping a COSHH record of exposure. This correlates with the results of Question 19 on the perceptions of whether a nanomaterials presents a health risk or not.

Only 31% of the departments knew whether the engineering controls had been tested and 33% had the records of thorough examination and test for them. This is of concern as not all departments in universities have full control or responsibilities over the engineering controls. In many universities these fall under the control of university estates departments. Estates look after the buildings and infra-structure of the universities and it is them that get the engineering controls (e.g. fume extraction cupboards) thoroughly examined and tested, carry out maintenance and keep the records for these activities. Improvements in communication between estates and those using engineering controls needed to be made in some universities.

Only 33% of the departments thought they should retain records that they had carried out training on how to use the engineering controls.

Keeping records of training on how use of respiratory protection was low at 13%, but this was not usually the main form of control in use.

Records of training in how to use gloves was higher at 47% which is encouraging as the dermal route was identified as the main route of exposure for nanomaterials by the majority of university departments.

Only 5% of the departments held records of carrying out environmental air monitoring, possibly due to the difficulty in measuring nanomaterials.

Table 17
Information available

Information	Yes	No	Don't know	Blank	Total dept.
COSHH Risk Assessment	66 (88%)	1 (1%)		8 (11%)	**75**
COSHH Exposure Records	9 (12%)	36 (48%)	6 (8%)	24 (32%)	**75**
Thorough Examination &Testing Reports on Engineering Controls	23 (31%)	22 (29%)	6 (8%)	24 (32%)	**75**
Records of Maintenance of Engineering Controls	25 (33%)	18 (24%)	9 (12%)	23 (31%)	**75**
Training on how to use engineering Controls	25 (33%)	21 (28%)	5 (7%)	24 (32%)	**75**
Training on how to use RPE	13 (17%)	24 (32%)	9 (12%)	29 (39%)	**75**
Training on use of Gloves	35 (47%)	16 (21%)	4 (5%)	20 (27%)	**75**
Environmental Air Monitoring	4 (5%)	35 (47%)	8 (11%)	28 (37%)	**75**

4.2 VISITS

A total of 9 universities across the UK and 45 research groups were visited by a specialist inspector (occupational hygienist) to see at first hand how they were controlling nanomaterials and in order to validate the findings from the responses on the feedback forms. Seven of the universities visited had returned feedback forms. The visits were broken down into main disciplines as shown in Table 18 below.

It is not always appropriate to use the word ‘departments’ in universities and it is better to identify those involved as research groups and link them back to the main discipline as a lot of the nanotechnology research involved more than one department or more than one discipline. Unlike other research, nanotechnology crosses all boundaries of science and breaks with the tradition of single disciplines and single departments. So each research group visited was linked to the main science discipline.

Table 18 shows that there is more nanotechnology research being carried out by the chemistry discipline of the universities. This confirms the findings from the feedback forms.

Table 18 **Main discipline**

Main discipline	Number of research groups	Percentage %
Engineering	4	9%
Chemistry	16	35%
Medicine	5	11%
Nanotechnology Centres	5	11%
Physics	5	11%
Life Science	4	9%
Textile and Design	1	2%
Materials Science	5	11%
Total	**45**	

Nanomaterials used in universities visited

Listing all the nanomaterials used by each research group would have taken up a lot of the visit time. Instead, the main nanomaterials used within each research group were identified. The list of nanomaterials used is extensive and for clarity has been presented here as a simple list to show the diversity of the nanomaterials used. The types of nanomaterials used across the nine universities visited included the following:

- All metal oxides Aluminum, Scandium, Titanium Vanadium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Yttrium, Zirconium, Niobium, Molybdenum, Technetium, Ruthenium, Rhodium, Palladium, Silver, Cadmium, Lanthanum (sometimes/often considered a rare earth, lanthanide), Hafnium, Tantalum, Tungsten, Rhenium, Platinum, Gold, Mercury, Actinium sometimes (often considered a rare earth, actinide), Gadolinium, Neodymium, Europium, Dysprosium. Ytterbium;

- Quantum dot CdTe/,CdSe , CdSe/ZnTe;
- Hydride of Magnesium, Lithium;
- Oxide wire of Gadolinium, Neodymium, Europium, Dysprosium, Ytterbium;
- Metals Ni, Fe, Co, Mg on a carbon support;
- Gold, silver biological nature conjugate;
- Silver, Gold, Platinum, Copper, Platinum, Palladium;
- Beads of Latex, polystyrene, nylon;
- Particles of Polystyrene, Polycarbonates;
- Cellulose, Nylon;
- Carbon Black, Multi walled Carbon Nano Tubes (CNTs), Single Walled CNTs, Metals on carbon, CNTs bound fibrous coating, CNTs bound on to solid surfaces;
- Fullerenes C60, hollow sphere, ellipsoid or tube. Spherical fullerenes are also called Bucky balls, Graphene;
- Magnetite;
- Silica;
- Inorganic oxides, silica, alumina, zirconia, ceria, yttria and oxides of tin and zinc;
- Sulphides of gold , copper, iron, arsenic;
- Gallium Arsenate;
- Polyethylene oxide;
- Organoclay - an organically modified phyllosilicate, derived from a naturally occurring clay mineral;
- Highly Conductive and Stretchable Silver Nanowire;

- Nitrate Cobalt, Silver, Zinc, Titanium; and

- Other materials such as Ethylenediamine, Methyl acrylate and Diesel exhaust particles.

The above list highlights the diversity of the nanomaterials being used in research but can only be viewed as a 'snapshot in time'. As research moves on, the nanomaterials used will change and develop, more will be added to the list, and some may be removed as they fail to deliver the properties and applications being sought.

From the visits to the research groups it was estimated that some 120 different types of nanomaterials were being used within the 9 universities visited. Each university carries out its own unique research with a nanomaterial but at the same time, collaborations between departments within a university and inter-university collaborations are also taking place.

People using nanomaterials

For comparison with industry the Labour Market Statistics classification was used to classify the university departments. Table 19 shows the findings. Using the Labour Market Statistics classification from the Office of National Statistics the departments were grouped into equivalent industry sizes (www.ons.gov.uk/ons); this indicated that 98% would be classed as small enterprises. These findings broadly reflect those found in the responses to the feedback forms.

Table 19 Labour Force Classification for number of workers using nanomaterials

Total number of workers	1 to 9	10 to 49	50 to 199	200 to 249	250 plus	No dept.
	36 (80%)	8 (18%)	1 (2%)			45 (100%)

In order to calculate the total number of workers using nanomaterials, the exact numbers of workers were extracted from each of the main disciplines visited. Table 20 shows the findings. The total number of workers using nanomaterials in the 9 universities visited was 266.

Table 20 Number of workers in each discipline using nanomaterials

Main discipline	Number of workers
Engineering	15
Chemistry	59

Medicine	22
Nanotechnology Centres	61
Physics	45
Life Science	16
Textile and Design	1
Materials Science	47
Total	**266**

Frequency and duration

The frequency and duration of work with nanomaterials was considered. Again, research groups were asked about the number of days per week spent working with nanomaterials. Table 21 shows the results.

'Varies' can mean anything from once every two weeks to once a year. Days per week are a poor indicator of duration within research. Most of the tasks carried out are of very short duration (from 10 minutes to 30 minutes) and can be carried out from once or twice a week or once or twice a month.

Like question 17 from the feedback form, there is a fairly even distribution over the five working days and it is clear that the time spent cannot be measured in the same way as it would be measured in industry. Research is difficult to quantify in terms of time as it varies during the three years over which the majority of research projects run.

Table 21
Time spent working with nanomaterials in days

Days per week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Varies**	**Total dept.**
	11 (24%)	**5 (11%)**	**5 (11%)**		**6 (13%)**			**18 (40%)**	**45**

Risk assessment

The quality of the risk assessment on the more general health and safety aspects for each research group was studied and where one had been carried out it was rated, following the visit methodology. Table 22 outlines the finding of the HSE assessment of the risk assessments against the research group discipline and gives an overview of the level of performance found.

Table 22
Risk assessment by discipline

Main discipline	Number of research groups	Risk assessment					
		None	Very poor	Poor	Satisfactory	Good	Excellent
Engineering	4	1			1	2	
Chemistry	16	2		4	4	1	5
Medicine	5				1		4
Nanotechnology Centres	5					2	3
Physics	5				3	2	
Life Science	4				1	2	1
Textile and Design	1	1					
Materials Science	5				1	3	1
Total	**45**	**4 (9%)**		**4 (9%)**	**11 (24 %)**	**12 (27%)**	**14 (31%)**

Only 9% of the research groups had not done or considered doing a risk assessment and a further 9% had done a 'poor' job. Overall 82% had produced one that was 'satisfactory' or better. Out of these, 38% achieved a rating of 'excellent'; these groups had gone beyond just filling in a form. They had regular review procedures in place, had consulted and researched the topic and had kept up to date with the rapidly moving area of nanotechnologies.

Of the four research groups that had not carried out a risk assessment, two were in the chemistry discipline. A further four groups, again from chemistry, had produced a poor risk assessment. However, five of the chemistry research groups did achieve a rating of excellent.

Control of Substances Hazardous to Health (COSHH) risk assessment

The COSHH risk assessment looks at the control of exposure to the specific substance that is potentially hazardous to health. The COSHH assessment for each research group, where available, was studied and given a rating, following the visit methodology. Table 23 outlines the findings of the HSE assessment of the COSHH risk assessments per discipline and gives an overview of the level of performance found.

Table 23 COSHH risk assessment by main discipline

Main discipline	Number of research groups	COSHH assessment					
		None	Very poor	Poor	Satisfactory	Good	Excellent
Engineering	4				2	2	
Chemistry	16	3		2	3	2	6
Medicine	5				1		4
Nanotechnology Centres	5					2	3
Physics	5	1			1	3	
Life Science	4					3	1
Textile and Design	1				1		
Materials Science	5				1	3	1
Total	**45**	**4 (9%)**		**2 (4%)**	**9 (20%)**	**15 (33%)**	**15 (33%)**

9% of the research groups had not carried out, or even considered carrying out a COSHH risk assessment and a further 4% had carried out a risk assessment that was considered ‘poor’.
However, on the whole, the standard of COSHH assessments was high with 86% achieving a ‘satisfactory’ rating or higher; 33% achieved a rating of ‘excellent’. These ‘excellent’ research groups had also implemented management controls, considered the route of exposure, frequency and duration of potential exposure and had carried out regular reviews. The COSHH risk assessments were readily available, and all tasks had been considered and emergency procedures had been put in place. The researchers in these research groups had been trained to a high standard and could only gain access to a laboratory when this had been achieved. All the researchers had to write their own COSHH risk assessments and were not allowed to proceed until the supervisor had approved them.

Of the four research groups that had not carried out a COSHH assessment, three were in a chemistry discipline. A further two groups, again from chemistry, had a ‘poor’ COSHH assessment. As chemists generally are used to dealing with hazardous substances this was worse than expected. However, a further six research groups had produced excellent COSHH risk assessments. During conversations with the under-performing chemistry groups their attitude to risk and to health and safety was found to be poor and this attitude was reflected in some of the other categories assessed for these research groups.

Information and training provided

The information and training assessment considered all the information and training given to those working with nanomaterials. The information and training for each research group was studied and, where a record was kept, was given a rating, following the visit methodology. Table 24 outlines the findings of the HSE assessment of the information and training assessments by discipline and gives an overview of the performance.

Table 24 Information and training by main discipline

Main discipline	Number of research groups	Information and training					
		None	Very poor	Poor	Satisfactory	Good	Excellent
Engineering	4				2	2	
Chemistry	16		1	4	2	4	5
Medicine	5				1		4
Nanotechnology Centres	5					2	3
Physics	5					5	
Life Science	4					4	
Textile and Design	1			1			
Materials Science	5				1	3	1
Total	**45**		**1 (2%)**	**5 (11%)**	**6 (13%)**	**20 (44%)**	**13 (29%)**

All research groups had provided information and training. However, five research groups in the chemistry discipline had provided ‘very poor’ or ‘poor’ information and training. On the other hand, five other chemistry research groups achieved a rating of excellent and these groups were assessed as having a positive attitude to health and safety. Overall, 86% of the research groups achieved a ‘satisfactory’ or higher rating for their information and training and 29% of the groups had a rating of excellent. These ‘excellent’ groups had trained all of the researchers to carry out COSHH risk assessments, given general training in health and safety, examined their researchers on the training received (by way of 20 questions) which ensured that they had understood it, and records were kept of all of the training and information given. In some of these research groups, the head of research did spot checks of health and safety to ensure good practice was maintained.

Engineering controls provided

All aspects of the engineering controls were assessed. The engineering controls for each research group were observed and individuals questioned on its use. All paperwork was examined and a rating following the visit methodology was given. Table 25 outlines the finding of the expert assessment of the engineering controls per discipline, and gives an overview of the performance

Table 25 Engineering control assessment by main discipline

Main discipline	Number of research groups	Engineering controls					
		None	Very poor	Poor	Satisfactory	Good	Excellent
Engineering	4	1		1	1	1	
Chemistry	16	3	2	1		6	4
Medicine	5					3	2
Nanotechnology Centres	5	1				1	3
Physics	5	1				4	
Life Science	4	1				3	
Textile and Design	1	1					
Materials Science	5				1	4	
Total	**45**	**8 (18%)**	**2 (4%)**	**2 (4%)**	**2 (4%)**	**22 (49%)**	**9 (20%)**

18% of the research groups did not use engineering controls. 8% had engineering controls that were either ‘very poor or ‘poor’. 73% of the research groups had either ‘satisfactory’ or a higher rating of engineering controls in place; 20% of these were given a rating of ‘excellent’. These ‘excellent’ groups had kept records of thorough examination and tests, had maintenance procedures in place, and had given the researchers training on how to use the controls. The researchers knew what to do in an emergency, knew who looked after the controls and how to contact them. Daily checks procedures were in place and records were kept. Some research groups had dedicated ‘nanomaterials only’ fume cupboards.

The poorest performing discipline was chemistry with two groups from this discipline having a rating of ‘very poor’ and one having a rating of ‘poor’.

The visits validated the findings from the responses to the feedback forms which showed that engineering controls were used by 72% of the departments.

Respiratory protective equipment (RPE)

80% of the research groups did not use RPE, consequently the use of RPE was investigated, but a rating was not made on its adequacy.

Table 26 Respiratory protective equipment assessment by main discipline

Main discipline	Number of research groups	Respiratory protective equipment (RPE)			
		Assigned protection factor	Yes	No	Face FIT test nos.
Engineering	4	20	1	3	1
Chemistry	16	20,20,40, not Known,4,4,4,4	8	8	8
Medicine	5	N/A	0	5	0
Nanotechnology Centres	5	N/A	0	5	0
Physics	5	N/A	0	5	0
Life Science	4	N/A	0	4	0
Textile and Design	1	N/A	0	1	0
Materials Science	5	N/A	0	5	0
Total	**45**	N/A	**9 (20%)**	**36 (80%)**	**9 (20%)**

Only 9 research groups out of 45 used RPE i.e. 80% of the groups did not use RPE and correctly relied on engineering controls and other more suitable controls, to control exposure to nanomaterials.. Out of the nine who used RPE none had carried out a face-fit test. Face-fit testing is essential to ensure that the RPE provided correctly fit the individual wearer's face. Of those research groups using RPE, eight were from the chemistry discipline and four of the groups were found to be using masks with an inappropriate assigned protection factor. This is a very poor standard for RPE
All groups found to be using inappropriate RPE were told at the time to put the correct RPE in place and to carry out face-fit testing. This was implemented by all of the departments and noted by the safety officers in order to ensure appropriate RPE and testing was implemented across each university.
.

Gloves (PPE)

The use of gloves was investigated and observed. Observations on the type of glove used and whether training had been provided in the correct putting on and removal of gloves, along with whether a second pair of gloves were worn when handling CNTs are shown in Table 27:

Table 27 Glove assessment by main discipline

Gloves (Personal Protective Equipment)							
Main discipline	**Number of research groups**	**Disposable gloves used in all research groups**					
		Second pair of gloves worn handling CNTs only	**Yes gloves on/off training**	**No gloves on/off training**	**Latex (powder free)**	**Nitrile**	**No gloves**
Engineering	4	0	2	2	3	5	0
Chemistry	16	2	0	16	15	15	1
Medicine	5	1	3	2	1	5	0
Nanotechnology Centres	5	1	1	4	3	5	0
Physics	5	0	1	4	4	5	0
Life Science	4	2	0	4	2	4	0
Textile and Design	1	0	0	1	1	0	0
Materials Science	5	0	3	2	4	5	0
Total	**45**	**6 (13%)**	**10 (22%)**	**35 (78%)**	**33 (73%)**	**44 (98%)**	**1 (2%)**

All research groups except one chemistry group wore disposable single-use gloves. The gloves provided were made from either powder-free latex or nitrile rubber. Only 22% of the research groups had been given formal training on how to put on and remove gloves. However, the other groups that had not received formal training, appeared to be adequately removing gloves without spreading contamination on to themselves when observed. There were six research groups that wore a second pair of disposable gloves over the first when working with carbon nanotubes; the correct procedure for handling this type of material.

Laboratory Coats (Personal protective equipment (PPE))

The use of laboratory coats (PPE) was investigated, but a rating was not made on the adequacy. This was because all except the physics groups routinely wore laboratory coats. Table 28 shows which groups used PPE, how frequently the laboratory coats were changed and whether these were laundered by the University or by individual workers taking them home.

Table 28 **Personal protective equipment assessment by discipline**

Main discipline	Number of research groups	Laboratory coats (Personal Protective Equipment)										
		Material			Frequency of Changing Coat					Laundry		
		Cotton	Cotton/ Polyester	No coat	Weekly	Monthly	3 Months	6 Months	No schedule	Yes	Home	Waste
Engineering	4	1	3		1				3	3	1	
Chemistry	16	10	6			5	1	1	9	12	2	2
Medicine	5	1 disposable Tyveks	5		3	1			1	5		
Nanotechnology Centres	5	2	2 1Nylon **(2%)**		2	1		1	1	5		
Physics	5	3	1	1	1				4	5		
Life Science	4	2	2			2			2	4		
Textile and Design	1		1						1		1	
Materials Science	5		5			2			3	5		
Total	**45**	**18 (40%)**	**25 (55%)**	**1 (2%)**	**7 (15%)**	**11 (24%)**	**1 (2%)**	**2 (4%)**	**24 (53%)**	**39 (87 %)**	**4 (9%)**	**2 (4%)**

The response to feedback forms had indicated that protective clothing was only used by 53% of the research groups. All research groups, except two, wore reusable laboratory coats made from either cotton or from polyester/cotton. One group used nylon laboratory coats in the clean room (to keep the clean room clean), and one group used disposable Tyvek when handling carbon nanotubes, which is in keeping with HSE's guidance. The difference in practice compared to the findings from the feedback forms was thought to be due to a failure to understand the terminology used on the form and probably accounts for the number of forms left blank for this question.

Laboratory coats were generally used more as a protection from other chemicals rather than nanomaterials specifically. Whilst laboratory coats do offer some protection for a worker's clothes, they must be considered as PPE and therefore requiring to be changed and laundered regularly to provide protection, as they will become contaminated over time. 53% percent of the research groups had no set schedule for changing the laboratory coats with coats being changed when an individual worker felt it was necessary. 87% of the research groups did have the coats laundered but workers in four research groups took the coats home to wash themselves. As a result of the visits, advice was given and home washing was stopped immediately. Two of the chemistry groups found it to be more cost effective to use reusable coats and throw them away when contaminated, rather than have them laundered every month.

HSE Website

During the visit the individuals met were asked the three questions about HSE's Nanotechnology website. The findings are set out in the Table 29 below

Table 29 Question on HSE's Nanotechnology website

Number of Research Groups	**Format like to receive H&S Information**	**Visited the HSE Nanotechnology Website?**		**Thoughts on HSE Nanotechnology Website After Visiting It?**	
		Yes	No	Useful	Not useful
45	• pdf on website (42) • e-mail (3) • Bulletins (1)	21 (47 %)	24 (53%)	19 (90%)	2 (10%)

Staff in 47% of research groups had visited the HSE nanotechnology website. Of those who had visited the HSE nanotechnology website 90% of them found it useful. When asked what else they would like to see on the website they identified five areas for development:

- More toxicology information.
- More nanomaterials-specific information.
- More guidance on specific controls for specific types of nanomaterials.
- More about safe handling of nanomaterials.
- Future events i.e nano workshops, seminars or conferences.

5.0 DISCUSSION

The feedback form exercise took place in early 2011 and the visits during the summer of 2011. Despite some of the challenges encountered, in particular those relating to the terminology used in the feedback form, some universities were able to complete the form. The responses have been interpreted. Overall, the combination of the responses to feedback forms and the findings from the visits have provided a good insight into how nanomaterials were being used by UK universities. However, this only gives an indication of what was going on at that particular time. The use of nanomaterials and the nature of research is continually evolving and changing.

6.0 CONCLUSIONS

The majority of work with nanomaterials was carried out in research laboratories within the ‘campus’ of the universities rather than by small ‘offshoot’ companies.

Information from the visits and feedback forms showed that most of the research was being carried by the chemistry departments. However, a lot of the nanomaterials research involved more than one university department or more than one scientific discipline. Unlike some other research, nanomaterials research crosses the boundaries of science disciplines, so it makes it difficult to assign one piece of research to one discipline. Chemistry along with material science accounted for the major disciplines working with nanomaterials during the time period of this project.

The range and type of nanomaterials used is varied and diverse.

Each university carries out its own unique piece of research with a nanomaterial, but at the same time collaborations between departments within a university and collaborations with other universities can take place.

The general perception of those working with nanomaterials as to whether there is a health risk is split with 36% considering that nanomaterials did present a risk and 37% that they did not. There is a perception that nanomaterials have not been tested extensively and, therefore a health risk may be present, particularly as all chemical materials represent some degree of hazard.

In most cases research groups considered that nanomaterials should be treated with caution as there was a lot of uncertainty about whether they were hazardous. However, if the work was also carried out in fume cupboards with generally small amounts, or if nanomaterial was in a liquid or bound to a substrate then the risk of exposure was considered to be minimal.

It was encouraging to see that the university departments in the main appear to be following the COSHH hierarchy of control and that engineering controls and management controls are used rather than relying on RPE/PPE to control workers’ exposure to nanomaterials.

ANNEX 1

Blank feedback form sent to universities by The UK NanoSafety Group

Nanomaterial Feedback Form

PLEASE FILL IN ONE FORM FOR EACH DEPARTMENT OR PROJECT WITHIN THE INSTITUTION

1. **Role of person filling in form.** *Please write down the name and role of person filling in the form.*

2. **Institution/Department/Project Information.** *Please write down the name and address including postcode.*

3. **Contact details.** *Please write down the name of a contact person with phone number and email address details.*

4. **Facility type** *(tick all that apply)*

Facility	*Tick all that apply*
Research Laboratory	
Pilot Plant	
Production Manufacturing	
Other (please specify by typing in the box)	

5. **Location**

Location	*Tick appropriate box below.*
Off Campus	
On Campus	

6. Subject Classification
Please select the box which best classifies the subject activities on site

Tick appropriate box below.	**Subject Activity**
	Medicine
	Pharmaceutical
	Biological
	Chemistry
	Electrical Engineering
	Mechanical Engineering
	Aeronautical Engineering
	Material Science
	Environmental Science
	Agriculture
	Biotechnology
	Energy
	Transportation
	Information Technology
Other (please specify by typing in the box?)	

7. Nanomaterials used/or as per project?
Please write down all the nanomaterials used on site (e.g. Nickel wires, cadmium dots etc)

8. Physical form of the nanomaterial?
Please select the box(es) which describes the nanomaterial type

Physical type	**Powder**	**Liquid**	**Vapour**	**Mist**	**Gas**
Please tick appropriate box(es)					
Other (please specify by typing in the box)					

9. Where do you obtain your nanomaterials?
Please tick all appropriate box (es)

	Yes	**No**	**Don't know**
Manufactured on-site			
Sourced in from UK			
Sourced in from Europe			
Sourced in from USA			
Sourced in from China			
Sourced in from India			
Sourced in from Australia			
Sourced in from Malaysia			
Other source *Please specify?*			

10. Rough estimate of quantities of all nanomaterials used per month?
Please write name of nanomaterial(s) and select the appropriate box to give an estimation of the quantities used and indicated in time period box how long the materials have been used in months

Nanomaterials	<10 mg	50 mg	1 g	10 g	>0.5kg	Time Period (Months)

11. Rough estimate of quantities of nanomaterials manufactured per month?
Please write name of nanomaterial(s) and select the appropriate box to give an estimation of the quantities manufactured and indicated in time period box how long the materials have been manufactured in months

Nanomaterials	<50 mg	10g	0.5kg	1kg	>1.5kg	No manufacture	Time Period (Months)

12. How long has the Institution been using nanomaterials?

Please select the box to give an estimation of the years been using nanomaterials by institution/department

Time in years	< 0.5	1	2	3	4 plus

13. People using nanomaterials?

Please select the box to give an estimation of the number of workers on site

Total Number of Workers	1 to 9	10 to 49	50 to 199	200 to 249	250 plus

14. Gender of workers using nanomaterials?

Please write the number of each gender using nanomaterials

Total Number of Workers	Female	Male

15. Age range of workers using nanomaterials?

Please select the box(es) to give an estimation of the age of workers using nanomaterials

Total Number of Workers	18 to 21	22 to 31	32 to 41	42 to 51	52 plus

16. Average daily time spent using nanomaterials?

Please select the box to give an estimation of the time spent using nanomaterials per day

Time spent in hours per day	1	2	3	4	5	6 plus

17. Average numbers of days per week using nanomaterials?

Please select the box to give an estimation of the number of days workers use nanomaterials

Days per week	1	2	3	4	5	6	7

18. Disposal of nanomaterials?

No waste (all nanomaterial used)	
Specialist waste	
Landfill	
Incineration	
Other (please specify by typing in the box):	

Please select the box(es) to indicate the way you dispose of nanomaterials from the site

19. In your opinion do you think nanomaterials present a heath risk?

Health Risk	Yes	No	Don't know

If you answer Yes or No to question 19, please write down why you hold this opinion?

Types of Controls?

Please tick yes or no to indicate which type of control are used to control exposure to nanomaterials?

Type of Controls	Yes	No	Don't Know
MANAGEMENT OF PEOPLE AND ACTIVITIES (i.e. restricted access)			
ENGINEERING (i.e. Fume cupboard +HEPA filter; Open-fronted spray booth; Downdraught booths)			
RESPIRATORY PROTECTION (i.e. Disposable masks, air fed etc)			
GLOVE (i.e. Disposable)			
PROTECTIVE CLOTHING (i.e. Tyvek suits)			

20. In your opinion what is the main route(s) of exposure for the nanomaterials used on site?

Please tick all that apply

Route of Exposure	Yes	No	Don't know
Inhalation?			
Dermal? (by skin)			
Ingestion? (by mouth)			
Injection			

21. Information available?

Please tick the appropriate boxes if the following information is kept on record for the project

Information	Yes	No	Don't know
COSHH risk assessment			
COSHH exposure records			
Thorough examination & testing reports on engineering controls			
Records of maintenance of engineering controls			
Training on how to use engineering controls			
Training on how to use RPE			
Training on use of gloves			
Environmental Air monitoring			

ANNEX 2

Types of nanomaterials used in universities in the UK

The types of nanomaterials use by research groups in the UK as extracted from the feedback forms exercise carried out in 2011 are listed below:

Magnetic Nanoparticles.

Diesel exhaust particulates.

Copper, Nickel, Spinel doped with chromium (III), Yttrium aluminium oxide doped with cerium, Yttrium oxide doped with europium, Zinc sulphide doped with manganese, Tin oxide doped with antimony, Silver, lanthanum phosphate doped with either europium, Cerium or Thulium, Lithium aluminium oxide doped with iron.

Various carbon blacks, Single wall carbon nanotubes, Multiwall carbon nanotubes, Functionalised carbon nanotubes, Graphene platelets, Mixed refined fullerenes, Various carbons graphitic, Graphite nanosheet, Carbon nanotubes single walled carboxylic acid functionalised. Carbon nanotubes in organic solution. Carbon nanotubes in aqueous solution, Carbon nanotubes in amide functionised solvent solution, Nanodiamonds.

Self assembled Protein fibrils.

Phosphors, magnesium, carbon nanotubes and catalysts, silicon.

Nanowires, Nickel long, Nickel short, silver 3-35µm.

Oxides Iron, Ytterbium , Yttrium, Indium , Zirconium Cobalt monoxide, Titanium silicon, Copper (II) , Fullerene- C60, Chromium (III) Cerium , Nickel , Titanium oxide rutile, Titanium oxide anatase, Silicon , Magnesium , Cobalt, Zinc ,Aluminium, Calcium Gadolinium Most metals in the periodic table either as oxides or metals, some sulfides, phosphates, and nitrides. Including Hydroxyapatite, Titania, Cadmium sulfide, Zinc sulfide, Lead sulphide, Barium titanate, Pt, Rh, Pd, WO_3, SiO_2, Ag, and solid solutions of any of the above.

Magnetite dispersion, haematite dispersion.

Aluminium oxide nanowhiskers. Cellulose nano-whiskers.

Alumina.

Silver metal powder, Silver metal nanopowder.

Gold Nanocages, Nanoparticles, Gold nanorods, nanoshells, colloid (5 nm diameter).

Gold, silver, palladium and platinum nanoparticles. Au, Ag, Pd, MoS_2, Cu clusters.

Quantum dots,CdSe quantum dots, PbS quantum dots, aka ganeiteiron, carbonyl, Qtracker, Qdot-NH, Qdot-COOH, Colloidal quantum dots made of the following semiconductors CdS, CdSe, ZnS, PbS, PbSe Silicon quantum dots., Cadmium sulphide quantum dots, zircon nanoparticles doped with transition metals (europium, terbium, and cerium).Colloidal lead sulphide PbS quantum dots.

Cellulose and starch nanocrystals, Nanocrystalline TiO_2.

Various fumed silicas, SiO_2 nanoparticle suspensions, Quartz (micro), Silica nanospheres Silica sols, and Silica nanoparticles.

Poly (methyl methacrylate), Polystyrene, Various silica’s, Poly NIPAM, Aminated polystyrene beads, Polybeads, Polystyrene nanospheres polymer nanoparticles.Polystyrene (20nm, 200nm) Polyplexes.

Polyvinyl pyrrolidine capped silver nanoparticles Vinyl polymers (styrene and vinyl pyridine etc).

Fluorescent polystyrene beads (10µm), Fluorescent polystyrene beads (3µm), NM-101 20nm and 200nm fluorescent polystyrene beads.

Latex Bead NH, Latex Bead COOH.

Nanomag-D-SPIO, Nanomag-D-SPIO NH,Nanomag-D-SPIO COOH.

Urban dust (NIST), Endorem, Sinerem.

Protein A Immunogold conjugate.

Superparamagnetic nanoparticles.

Styrene maleic acid lipid particles.

[6,6]-Phenyl C61 butyric acid methyl ester (PCBM).

ANNEX 3

Quotes from the feedback forms on the different disciplines on perception of health risks of nanomaterials

Chemistry

‘This depends on their formulation. If materials are created in carefully controlled environments by skilled personnel using appropriate methodology there is no risk. However, if risk is not known and hence assumed toxic – especially if equivalent bulk materials are toxic.’

‘Nanomaterials can be put into one of three classes. Each has its own risks and they should not be discussed as being equally dangerous. The department uses colloids exclusively. To date there are no consistent reports of colloids being dangerous. Indeed they are frequently used in medical preparations e.g. scintigraphy and cell biology.’

‘Nanomaterials’ is a very broad term. The nanoparticles mainly used are dealt with are prepared in solution and incorporated into a polymer membrane and therefore the health risks are minimal.’

‘If the materials are formed in solution and always remain in solution. There should be no air exposure. The materials are disposed into specialist chemical waste and therefore there should be no risk.’

‘No real exposure to nanoparticles as the nanostructures are intimately bound to substrate and contained within an UHV chamber. When sample is removed from chamber to atmospheric condition, there is little potential of removing particles from surfaces as they are bound to the surface. Quantities are extremely small and of the order of only a few monolayers at most. Due to the very small quantities produced and the safety precautions taken in synthesis and use there is no risk.’

‘All materials represent some degree of hazard. The additional hazards associated with nanomaterial powders relates to their fine particles. Any chemical presents a risk. Good laboratory practice minimises the risk. If work in fume cupboards with generally small amounts which are usually dispersion in a solvent there is no risk.’

‘Lead is a known heavy metal and can be accumulated in the body leading to health risks. However, the health risks can be easily controlled and avoided by e.g. (i) handling the minimum amount needed for the studies; (ii) use of precautions to prevent the direct exposure (gloves, fume hood, etc).’

‘I think it is very dangerous to make statements as “are nanomaterials dangerous”. Every material is different and needs to be considered on its own merit. We wouldn’t make statements like “are animals dangerous”. Some metallic nanoparticles are very active catalysts so they will be dangerous.

Cellulose and starch nanoparticles are natural materials but might be cytotoxic under certain circumstances.'

'Certain types in certain forms **MAY** present a health risk, but to suggest that all nanomaterials are intrinsically hazardous are as stupid as suggesting that all chemicals are toxic. I have worked on a project assessing ecotoxicology of polymer nanoparticles and it is clear that even within a specific class of broadly similar nanomaterials, there can be vastly different effects depending on size and surface chemistry. Generalisation in this area is problematic.'

'As nanomaterials differ in size from their 'bulk' counterparts; their properties, chemistry etc differ. In 2008 a study was performed in Sweden introducing particular oxides in to human tissue found that iron oxide, titania and zinc oxide posed little or no DNA damage, where as carbon nanotubes and copper oxide caused wider scale DNA damage and identified as a clear health risk. **HOWEVER**, providing sufficient precautions are undertaken in respect of handling, minimising routes of intake etc, the risks are minimal and in line with substances encountered on a daily basis in an open environment.'

'Respiratory absorption of airborne nanoparticles may occur through the mucosal lining of the trachea or bronchioles or the alveolus of the lungs.
In some cases nanoparticles have been shown to migrate through skin and be circulated in the body.'

'If ingested some types of nanoparticles might be absorbed and transported within the body by the circulatory system.'

'Many Nanomaterials synthesised are novel materials with properties differing to typical powders or larger particulate substances. Therefore there hazards are often unknown and should be handled accordingly.'

<u>Bioscience</u>

'A cellulose nanoparticle is natural materials, but might be cytoxic under certain circumstances and therefore has to be considered a risk. Currently initiating an MRC/NERC funded study to assess the potential for nanoparticle cellular toxicity. Thus, in my opinion there is sufficient cause for concern that this should be investigated.'

'The polystyrene nanoparticle suspensions have been widely used in biomedicine for decades (for latex agglutination tests). We take steps to minimise human contact (personal protective equipment) and only dispose of them as chemical waste. The nanoarrays are not considered "nanomaterials" as they are bulk objects that happen to have nanoscale components, similar to a computer containing a microchip that has nanoscale transistors so there is no risk.'

'The material produced is neither volatile nor does it come into contact with the skin so there is no risk.'

Physics & Astronomy

'The quantities we produce are tiny (~µg) for fundamental research and there is little or no direct exposure to the scientists, Standard procedure in our clean rooms. The quantities of all nanomaterials used are limited and the control measures are strict. So the risk is minimal.'

'This depends upon the material being studied. Milk is nanomaterial but I drink gallons of it. Asbestos is also a nanomaterial and I try to avoid it. This strikes me as badly informed question. Should this question read 'In your opinion do you think that the nanomaterials that you use present a health risk?' If so, the answer is probably not, but the truth is that nobody really knows – this is part of what the project aims to find out.'

'The the questions is so generic that essentially all materials present a health risk in some form or shape.'

Engineering

'The answer is "Yes" since from reference to relevant literature and being aware of a number of issues, such as they are not detectable by the human eye when airborne and when ingested or inhaled can aggregate in cells. In our case, given the small amounts used and the manner in which they are processed I believe the risk to be minimal. If you require a more specific answer tailored to our use of nanomaterials then I would argue that there is no cause for concern or requirement that stricter controls be implemented than we employ already.'

Environmental Science

'Due to the current research available on CNTs and the evidence that respiratory irritation can occur with any dust/small particles, these compounds are treated as hazardous and control measures are employed.'

'Non-toxic iron particles are made, and always kept is slurry, so inhalation is unlikely. Slurries handled using microbiological techniques so ingestion unlikely. Gloves worn in the laboratory so dermal contact minimal.'

'As toxicologists all of our time is concerned with assessing the potential hazards and risks of nanomaterials. We have found over 15 years of research that particles of smaller size are often more hazardous than larger particles of the same material. This does not necessarily relate to induction of death (of animals or cells), but rather to sub lethal effects that can lead to disease. We do not see a uniform effect for all nanomaterials, some are clearly more toxic than others, and there seems to be a relationship between physicochemical characteristics and toxicity. For example factors which enhance toxicity include composition (e.g. Ag, ZnO and Cadmium telluride quantum dots are toxic due to their chemistry and sometimes due to the release of soluble toxic ions), charge (positive is more toxic than negative) as well as aspect ratio (fibre-like nanomaterials that are durable and greater than 10 um in length are more likely to be toxic than shorter fibres). The work we have done covers humans and the environment. The human work has looked at the respiratory, ingestion and injection routes of exposure, and the targets of toxicity studied include the lung, gastrointestinal tract, macrophages, the liver and endothelium. The environmental work has included aquatic invertebrates, aquatic sediment dwelling invertebrates, freshwater algae, marine macroalgae and mussels. Our human studies include mechanistic toxicology, trying to explain how nanomaterials induce cellular responses.'

'Nanomaterials should not be treated as a homogeneous category – there is evidence that some particles in some physical form can present a health risk in animal models, other particles will not be harmful, or not more harmful than 'conventional' chemicals.'

Materials/Materials Processing

'Nanomaterials, like all chemicals in a research laboratory, are safe when handled appropriately.'

Medicine

'Nanomaterials cannot be generalized. The one we us don't, they are polyesters and undergo ester hydrolysis and eliminated through citric acid cycle as carbon dioxide and water. The quantities are too small, and we always use appropriate safety protection. Small concs used (4nM) and all users must adhere to writen SOP's and Risk asssesments.'

'Generation of air-borne particulates will present a barrier to those likely to inhale them. LEV, RPE required.'

Pharmacy/Pharmacy & Pharmaceutical Sciences/Pharmacy & Biomedical Sciences

'This is difficult question to answer. Theoretically the nanomaterials used in this project are designed for biological applications and are designed to be not toxic. However, the relatively short time of the use of nanomaterials in medicine makes it difficult to make prediction on long term.'

'Our nanomaterials are always dispersed in solvents, mainly water. These materials are not able to penetrate the skin. No aerosols are generated during experiments. Very little chance to be accidently ingested.'

'There is no evidence that the nanomaterial behaves or presents a risk different to the parent chemical entity, i.e. polyacrylamide. The dried nanomaterial should behave and present the same risk as the dried polyacrylamide powder. Similarly, the solution or nano-suspension of the nanomaterials should present the same risk as a solution of polyacrylamide.'

Chemical Engineering/Chemical Process Engineering

‘Broadly speaking, some nanomaterials pose a health risk and most don’t. Long term effects are unknown. Those used in our research don’t.’

‘The toxicity of nano-materials depends very much on the material itself. In general, nano-materials should not be regarded as completed different from bulk materials. However, some nano-materials could be dangerous which need specific investigation. It is sure not all nano-materials are toxic’.

Engineering & Electronics

‘Although not included in the stats this form does say – “The injection of metallic nano particles (specifically silver nanoparticles) into the food chain may be a real risk to health as the bacterial suppression role of these particles may also impact on non-bacterial, benign biological structures.”
The health risk associated with material is currently under investigation. May cause irritation to skin, eyes, respiratory tract and gastrointestinal tract.’

Material Sciences

‘This refers to our use of nano materials, not such material in general. Our use is very limited. There seem to be indications that some nano-materials may present health risks. Until full evaluations are available caution would be well advised, particularly in the light of the risks associated with some of the materials at the non-nano scale e.g. Ni.’

Nanoparticles are small enough. They might have the ability to even enter in people’s skin or breathing system without being noticed. This might cause risks for the health of human beings.’

Other (Multidisciplinary)

‘The overall perception is that nanomaterials have not been tested extensively, and therefore a health risk exists.’

‘Nanomaterials **can** be a risk - some are carcinogenic, some could cause lung related diseases, some could cause skin reactions. These are all already known. We don’t tend to deal with dry nanopowders in large quantities but use formulations and liquid suspensions. As with all chemical process
Risk = hazard x exposure. If the materials are hazardous, then exposure must be minimised to minimise risk.’

Biotechnology

‘Care should be taken for skin application (as penetration is possible) particularly as our nanoparticles have biological functionality added – gloves at all time.’