Risk Associated With Use Of Nano Material

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Abstract

The Next big thing is going to be this small nano which will transform the world with facilities of latest products and enhanced characteristicsmaterialsfor improved quality of life. In everyday products, use of nano materials are at large scale due to its properties of being light weight and strong. Bio compactable nano materials are available for the field of medical and drugs. Till date only advantages are seen but when nano material is used at large scale, potential health risk and damage to environment are to be considered. Risk assessment, review of regulations are discussed here.There is a need for reference nanomaterials since this would allow the assessment of fate and behaviour as well as effects, which could then be related to the material's properties and characteristics. It would also allow comparisons between different nanomaterials. Some reference nanomaterials are available, but they are spherical model materials which are certified primarily for size and are used mainly to calibrate instruments which measure particle size. The absence of well-defined parameters to measure and standardise test protocols is identified as a major obstacle for reference material production

Index terms: *Nanotechnology safety, risk assessment, risk mitigation, nano-safety, nanotechnology regulation, nanomaterial properties*

1. INRODUCTION

Nano technology means creation of materials at the nanometre (nm) scale. E.g. human hair 70,000 nm in diameter, a red blood cell is 5,000 nm wide, organic molecules from 0.5 to 5 nm.[1]

In nature numbers of examples are there for nano materials like lotus surface is acting as nano surface, nano deoplet of milk, nano size protein etc. As a byproduct of many processes, nano particles are produced like fire, disel engine, manufacturing processes etc. it has applications in medical, building materials, cosmetics etc.

In era of 21st centrury, anno technology is considered as most innovative field. Ceritan health risks are associated with use or exposure of production and/ or nano materials. Major impacting factors for nano materials are: Exposure, traslocation, interaction. Assessment of health risks depends on use of quantity of material, level of nitration, toxicity of materials.

1.1 Benefits of nanotechnologies

Nanotechnologies have many advantages beneficial to society, industry, the environment and health. They are helpful to many day to day issue and improve quality of life. Also capable for energy storage and efficiency, better diagnosis and treatment of disease etc.

2. Potential health concerns

Major concern of risk assessment is the general lack of high quality exposure both on human and nature. It is too challenging to measure the day to day exposure of anno materials and its impact on human being. For nano material exposed in atmosphere it is possible to measure its size and effect by equipments.Equipment can measure the presence of particles and not the type of particles, also it is difficult to measure the back ground or exact exposure of anno materials. Nano silver can be present in products such as washing machines, food industry, wound dressings and food supplements (Wijnhoven et al. 2009, WWICS 2009). Use of it in food industry can either benefit or harm to a great extent. (EFSA 2008). It is always recommended to take care of health in terms of inhalation, ingestion, or absorption of nano materials till specific evidence of its effect.

2.1 Detection andanalysis

Innovations in methods for assessment of nano particles in air or liquid are going on. The research instruments require skilled persons to operate and does not fit to be used in public health all the time. Mobile instruments are developed more in numbers which are easy to use so research pace is increased. (Mordas et al. 2008, Smith 2004). The guidelines for comparison, reproduction, repeat use of nano materials are still awaited (SCENIHR 2006). To produce facts for risk identification, assessment and management of risks ; more instrument with guideline of use are required to meet with requirement of getting number of data. SCENIHR (2006) has given study results for methods for nano materials use for detection and analysis. Nano particles in liquid can be found out by methods like absorption and scattering (Van Dijk et al. 2006).

Nonmaterial preparations for biological testing

Usually no change is observed in surface area of nano particles though having tendency of material to aggregate, an important parameter for interaction of nano materials with biological system. To administer nano particle in biological system, suspension or dry powder use is in practice. Best nano particles dispersions are studied including albumin, protein,phospholipids (Wallace et al. 2007) etc. these coating will change the properties of nano material and with change in it its biological reactions will also be changed. Level of exposure of nano materials is mostly studied for inhalation of workers. Exposure in atmosphere is difficult to say between manufactured or ambient particles. (Fujitani et al. 2008,; Kuhlbusch et al. 2004, Kuhlbusch and Fissan, 2006, Kuhlbusch et al. 2008a, Kuhlbusch et al. 2008b, Maynard et al. 2004,Tsai et al. 2008, Wake et al. 2002, Yeganeh et al. 2008). Diameter more than 400 nm are handled , in specific case handling of 100 nm particles was also observed. (Yeganeh et al. 2008).

The interface between nanomaterials and biological systems

With interaction of nano materials with fluid, irrespective of single or agglomerate, they may have coating of protein which will make difference in biomolecules and end result of biological changes can also differ. (Blunk et al. 1993, Cedervall et al. 2007, Labarre et al. 2005)

Translocation of nanomaterials

Dependency for same will be physical or chemical properties like surface charge, hydrophobicity, size, presence or absence of a ligand (Des Rieux et al. 2006).Similarity in CNTs and aspect ratios were of concern than safety of nano tubes. (Donaldson et al. 2006, The Royal Society and The Royal Academy of Engineering 2004). High Aspect Ratio Nanoparticles has been used to cover structures. Takagi et al. (2008) explained to examine the tumerogenicity of carbon nanotubes in p53-deficient mice.

General principles

Klaine et al. 2008 reviewed behavior of nano materials with help of colloidal science (Lead and Wilkinson 2006). The results of nano particle does not only depend on physical and chemical properties but also on receiving environment. (Chen et al. 2008, Chen and Elimelech 2008). Tendency of particles to agglomerate further gets associated with dissolved, colloidal and particulate matter of the environment. When nano particles come in contact of atmosphere, dissolution,speciation ,biological or chemical transformation , mineralization,agglomeration,settling etc. takes place.

Test methods for predicting environmental distribution

OECD methods to be verified further for administration of sample to be taken, in use for testing of physical and chemical parameters. Nano materials distribution are studied, still complex issues of fate and more information is awaited in this area. (Christian et al. 2008, Hassellöv et al. 2008, Klaine et al. 2008, Tiede et al. 2008;).

Exposure to nanomaterials in experimental studies

Testing of suspended nano materials in various exposure media methods are not proved yet. For uniform testing following are three approaches:
- dispersion with strong solvents and detergents
- dispersion by sonication
- dispersion by prolonged stirring (Crane et al. 2008, Klaine et al. 2008).

Strong solvent is mostly used suspension method e.g. tetrahydrofuran (THF) (Oberdörster 2004), dispersion agents e.g. sodium dodecyl sulphate (SDS) (Smith et al. 2007), bath or ultrasonication with filtration to remove aggregates (Lyon et al. 2006), stirring (Hund- Rinke and Simon 2006, Oberdörster et al. 2006), and combinations of these methods. Organic matter can keep nano particles suspended longer than a 1 % solution is suitable dispersant. (Hyung et al. 2007). With variable time (Klaine et al. 2008). Henry et al. (2007) has given use of solvents while dispersion of aqueous media which is one of the key issue.

Effect of nano material on enrionment are studied by various methods, mainly based on species studied as per range of them. Many have studied primary producers (mainly Pseudokirchneriella subcapitata (Franklin et al. 2007, Van Hoecke et al. 2008, invertebrates, (Fernandes et al. 2007, Hund-Rinke and Simon 2006, Lovern and Klaper 2006, Rosenkranz et al. 2009), and fish (such as rainbow trout Oncorhynchus mykiss, zebra fish Danio rerio, largemouth bass Micropterus salmoides, fathead minnow Pimephales promelas and Japanese medaka Oryzias latipes;(Federici et al. 2007, Griffit et al. 2007, Lee et al. 2007, Oberdörster 2004, Smith et al, 2007, Warheit et al. 2007, Zhang et al. 2007). Lyon et al. 2006 presented toxicity study. On experimental base study of dispersion of nano particles were used to study Synthetic detergents (Wick et al. 2007) and Tween (Warheit et al. 2003) who also mentioned that these can be toxic for them to expose while experimentation.

What is risk assessment and management

Risk assessment purpose is protection from harm of people but health and safety hazard of nano particle is yet to be understood. For nano materials if test is ot performed for evaluation then also precautionary measures are advised than to take risk. A risk assessment is required to take care of necessary prevention steps for people's health while using nano material for any work.In whatever case, proof by experiment of hazardous effect of nano material are not available, it is always advisable to follow prevention steps. If at all nano material use cannot be controlled , risk assessment will surely minimize potential risk.

The health risk management consist:
1. Steps for achieving specific steps
2. Rationale to justify steps

Property of material and its level of exposure gives risk effects to health.

Hazard Assessment

Assessment of hazard means evaluation of toxicity.Research so far supports response relationship. More use of nano particles in industries and commercial activity, exposure of it by inhalation, dermal contact or ingestion is common.

Assessment of dose-response of the ENP goes through following steps:
1. **Validation;**
2. **Verification**

Validation is process for test performed by different researchers with assumption that they are following guidelines and they are reproducible. Verificationis checking of results of experiments with actual data, if associated with animals then need to follow ethical aspects. For satisfying ethical considerations laid out by reduction, refinement and replacement vivo test are to be designed properly and needs to be focused. Dose response relationship is to be studied properly for sensitivity by ENP system. Physical and chemical characteristics responsible for toxicity re required to be taken care for meaningful hazard assessment. Figure 1 presents these and other key aspects of hazard assessment.
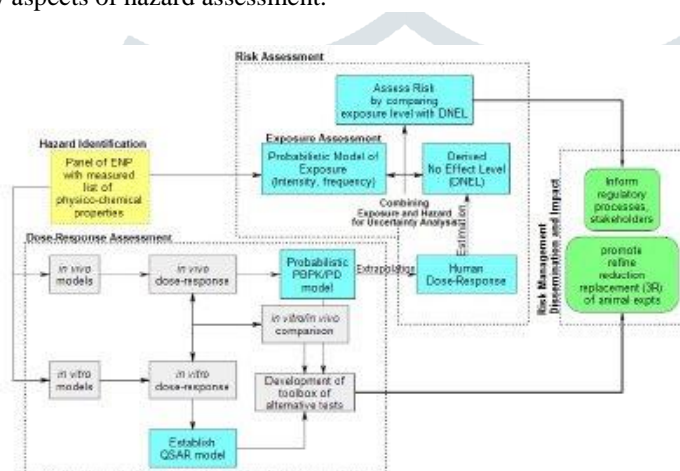

Figure1. The Hazard and Risk Assessment Process.

Exposure Assessment

For any harmful material, it can be considered that unless it is exposed to atmosphere , it is harmless. So exposure assessment is also important as risk assessment. From production to consumer, at any stage direct or indirect exposure of nano material is possible. Possibility of exposure cannot be ignored at any stage. Here figure 2 resents the various exposure sinarious.
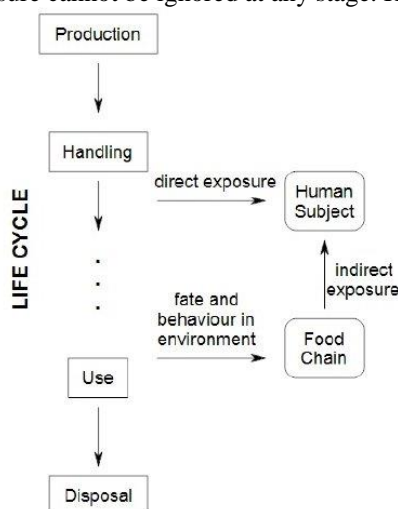

Figure 2. Exposure Assessment Rationale.

Risk Assessment and Management

Vivo results give hazardous assessment and risk assessment correlates the same in human context by extra polating results to humans through uncertainty factors. Inter animal or species differences may be compensated by these factors. This methods proves over estimation as impossible exposure limits comes as result which is not possible to handle.

Through experimental data, mathematical model for exposure dose response is more reliable approach. It can be extrapolated for human context and also can measure exposure level. This type of model is known as the Derived No Effect Level (DNEL) with advantage of including uncertainty, can be easily achieved by Monte Carlo simulation. By exposure assessment method, comparison between derived no effect level with total exposure can be done.Level of exposure of human needs to be verified by the model, increase in which represents a greater risk by nano materials.

By risk assessment whatever risk are projected, it is very important to study them and take decision of this projection effect. If socio economic system can easily afford the risk, it is accosted otherwise projected as greater risk.

Conclusion

Hazardous of risk assessment and rationale for exposure assessment is discussed. Method for risk assessment and management of exposure to ENP has been outlined. Major limitation here is dependency on exposure control. Risk prediction, its preventive steps are shown here. It is concluded that mathematical modeling is more reliable approach for prediction of risks as it can easily extrapolates and correlates with human.

References

1) WaltTrybula1DebNewberry2, Nanotechnology Risk Assessment, Nano technology safety, 2013, elseviwer, page 195 to 206

2) Bihari P, Vippola M, Schultes S, Praetner M, Khandoga AG, Reichel CA, et al. Optimized dispersion of nanoparticles for biological in vitro and in vivo studies. Part Fibre Toxicol 2008;5:14.

3) Blunk T, Hochstrasser DF, Sanchez JF, Müller BW, Müller RH. Colloidal carriers for intravenous drug targeting: plasma protein adsorption patterns on surface-modified latex particles evaluated by two dimensional polyacrylamide gel electrophoresis. Electrophoresis 1993; 14:1382-7.

4) Brouwer DH, Gijsbers JH, Lurvink MW. Personal exposure to ultrafine particles in the workplace: exploring sampling techniques and strategies. Ann Occup Hyg 2004; 48:439-53.

5) Cedervall T, Lynch I, Lindman S, Berggård T, Thulin E, Nilson H, et al. Understanding the nanoparticle-protein corona using methods to quantify exchange rates and affinities of proteins for nanoparticles. Proc Natl Acad Sci USA 2007; 104:2050-5.

6) Chen Z, Westerhoff P, Herckes P. Quanitification of C_{60} fullerene concentrations in water. Environ Toxicol Chem 2008; 27:1852-9.

7) Christian P, Von der Krammer F, Baalousha M, Hofmann T. Nanoparticles: structure, properties, preparation and behaviour in environmental media. Ecotoxicology 2008; 17:326-43.

8) Des Rieux A, Fievez V, Garinot M, Schneider YJ, Préat V. Nanoparticles as potential oral delivery systems of proteins and vaccines: a mechanistic approach. J Control Release 2006; 116:1-27.

9) Dhawan A, Taurozzi JS, Pandey AK, Shan W, Miller SM, Hashsham SA, et al. Stable colloidal dispersions of C_{60} fullerenes in water: evidence for genotoxicity. Environ Sci Technol 2006; 40:7394-401.

10) Donaldson K, Hill IM, Beswick PH. Superoxide anion release by alveolar macrophages exposed to respirable industrial fibres: modifying effect of fibre opsonisation. Exp Toxicol Pathol 1995; 47:229- 31.

11) Donaldson K, Tran L, Jimenez LA, Duffin R, Newby DE, Mills N, et al. Combustion-derived nanoparticles: A review of their toxicology following inhalation exposure. Part Fibre Toxicol 2005; 2:10.

12) Donaldson K, Aitken R, Tran L, Stone V, Duffin R, Forrest G, et al. Carbon nanotubes: a review of their properties in relation to pulmonary toxicology and workplace safety. Toxicol Sci 2006; 92:5- 22.

13) Donaldson K, Stone V, Seaton A, Tran L, Aitken R, Poland C. Re: Induction of mesothelioma in p53+/- mouse by intraperitoneal application of multi-wall carbon nanotube (Comment on: J Toxicol Sci 2008; 33:105-16). J Toxicol Sci 2008; 33:385.

14) Dufour EK, Kumaravel T, Nohynek GJ, Kirkland D, Toutain H. Clastogenicity, photo-clastogenicity or pseudo-photo-clastogenicity: Genotoxic effects of zinc oxide in the dark, in pre-irradiated or simultaneously irradiated Chinese hamster ovary cells. Mutat Res 2006; 607:215-24.

15) ECETOC. Testing Strategies to Establish the Safety of Nanomaterials—7–8 November 2005, Barcelona. Workshop Report No. 7. European Centre for Ecotoxicology and Toxicology of Chemicals, Brussels, Belgium;2006.

16) EFSA (European Food Safety Authority). Draft Opinion of the Scientific Committee on the risks arising from nanoscience and nanotechnologies on food and feed safety. Endorsed for public consultation on 14 October 2008. EFSA, Parma, Italy; 2008.

17) Federici G, Shaw BJ, Handy RD. Toxicity of titanium dioxide to rainbow trout (Oncorhynchus mykiss): gill injury, oxidative stress, and other physiological effects. Aquat Toxicol 2007; 84:415- 30.

18) Fernandes TF, Christofi N, Stone V. The environmental implications of nanomaterials. In: Monteiro- Riviere NA, Tran CL, editors. Nanotoxicology: characterization, dosing and health effects. Taylor and Francis, CRC Press, USA;2007.

19) Franklin N, Rogers N, Apte S, Batley G, Gadd G, Casey P. Comparative toxicity of nanoparticulate ZnO, bulk ZnO, and $ZnCl_2$ to a freshwater microalga (Pseudokirchneriella subcapitata): the importance of particle solubility. Environ Sci Technol 2008; 41:8484-90.

20) Fujitani Y, Kobayashi T, Arashidani K, Kunugita N, Suemura K. Measurement of the physical properties of aerosols in a fullerene factory for inhalation exposure assessment. J Occup Environ Hyg 2008; 5:380-9.

21) Hund-Rinke K, Simon M. Ecotoxic effects of photocatalytic active nanoparticles (TiO_2) on algae and daphnids. Environ Sci Pollut Res Int 2006; 13:225-32.

22) Hyung H, Fortner JD, Hughes JB, Kim JH. Natural organic matter stabilizes carbon nanotubes in the aqueaous phase. Environ Sci Technol 2007; 41:179-84.

23) Klaine SJ, Avarez PJ, Batley GE, Fernandes TF, Handy RD, Lyon DY, et al. Nanomaterials in the environment: behavior, fate, bioavailability, and effects. Environ Toxicol Chem 2008; 27:1825-51.

24) Lead JR, Wilkinson KJ. Natural aquatic colloids: current knowledge and future trends. Environ Chem 2006;3:159-71.

25) Lyon DY, Adams LK, Falkner JC, Alvarez PJ. Antibacterial acitivity of fullerene water suspensions: effects of preparation method and particle size. Environ Sci Technol 2006; 40:4360-6.

26) Lyon DY, Alvarez P.J. Fullerene water suspension (nC_{60}) exerts antibacterial effects via ROS- independent protein oxidation. Environ Sci Technol 2008; 42:8127-32.

27) Miller BG, Searl A, Davis JM, Donaldson K, Cullen RT, Bolton RE, et al. Influence of fibre length, dissolution and biopersistence on the production of mesothelioma in the rat peritoneal cavity. Ann Occup Hyg 1999; 43:155-66.

28) Mordas G, Sipilä M, Kulmala M. Nanoparticle Detection Using Nucleation Regime of the CPC. Book Nucleation and Atmospheric Aerosols: Springer; Netherlands, 2008. DOI 10.1007/978-1-4020- 6475-3 Copyright 2008 ISBN 978-1-4020-6474-6 (Print) 978-1-4020-6475-3 (Online) Part I DOI

29) Oberdörster G, Sharp Z, Atudorei V, Elder A, Gelein R, Lunts A, et al. Exrapulmonary translocation of ultrafine carbon particles following whole body inhalation exposure of rats. J Toxicol Environ Health Part A 2002; 65:1531-43.

30) Oberdörster E. Manufactured nanomaterials (fullerenes, C_{60}) induce oxidative stress in brain of juvenile largemouth bass. Environ Health Perspect 2004; 112:1058-62.

31) Oberdörster G, Sharp Z, Atudorei V, Elder A, Gelein R, Kreyling W, et al. Translocation of Inhaled Ultrafine Particles to the Brain. Inhal Toxicol 2004; 16:437-45.

32) Oberdörster G, Maynard A, Donaldson K, Castranova V, Fitzpatrick J, Ausman K, et al. Principles for characterizing the potential human health effects from exposure to nanomaterials: elements of a screening strategy. Part Fibre Toxicol 2005a; 2:8.

33) Oberdörster G, Oberdörster E, Oberdörster J. Nanotoxicology: an emerging discipline evolving form studies of ultrafine particles. Environ Health Perspect 2005b; 113:823-39.

34) Oberdörster E, Zhu S, Blickley TM, McClellan-Green P, Haasch ML. Ecotoxicology of carbon-based engineered nanoparticles: effects of fullerene (C_{60}) on aquatic organisms. Carbon 2006; 44:1112- 20.

35) SCENIHR. The appropriateness of existing methodologies to assess the potential risks associated with engineered and adventitious products of nanotechnologies. 2006. Available from: URL: (http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_003b.pdf)

36) Takagi A, Hirose A, Nishimura T, Fukomori N, Ogata A, Ohashi N, et al. Induction of mesothelioma in p53+/- mouse by intraperitoneal application of multiwall carbon nanotube. J Toxicol Sci 2008; 33:105-16.

37) Van Dijk MA, Tchebotareva AL, Orrit M, Lippitz M, Berciaud S, Lasne D, et al. Absorption and scattering microscopy of single metal nanopartcles. Phys Chem Chem Phys 2006; 8:3486-95.

38) Warheit DB, Carakostas MC, Bamberger JR, Hartsky MA. Complement facilitates macrophage phagocytosis of inhaled iron particles but has little effect in mediating dilica induced lung inflammatory and clearance responses. Environ Res 1991; 56:186-203.

39) Warheit DB, Reed KL, Webb TR. Pulmonary toxicity studies in rats with triethoxyoctylsilane (OTES)- coated, pigment grade titanium dioxide particles: bridging studies to predict inhalation hazard. Exp Lung Res 2003; 29:593-606.

40) Warheit DB, Hoke RA, Finlay C, Donner EM, Reed KL, Sayes CM. Development of a base set of toxicity tests using ultrafine TiO_2 particles as a component of nanoparticle risk assessment. Toxicol Lett 2007; 171:99-110.

41) Wick P, Manser P, Limbach LK, Dettlaff-Weglikowska U, Krumeich F, Roth S, et al. The degree and kind of agglomeration affect carbon nanotube cytotoxicity. Toxicol Lett 2007; 168:121-31.

42) Wijnhoven S, Herberts C, Hagens W, Oomen A, Heugens E, Roszek B, et al. Nano-silver. A review of available data and knowledge gaps. Report 360003001/2008 National Institute for Public Health and the Environment (RIVM), Bilthoven, the Netherlands;2009.

43) Yeganeh B, Kull CM, Hull MS, Marr LC. Characterization of airborne particles during production of carbonaceous nanomaterials. Environ Sci Technol 2008; 42:4600-6.