TERMINOLOGY REFERENCE SOURCES

ASTM, Terminology for Nanotechnology, E-2456-06, December 2006. Available for free download at: http://www.astm.org/cgi-bin/SoftCart.exe/DATABASE.CART/REDLINE_PAGES/E2456.htm?E+mystore

ASTM, Standard Terminology for Nanotechnology, WK8051. Under development: http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5601.htm?L+mystore+cprk8709+1177002851

Baron, P.A. and Willeke, K., Aerosol Measurement, Principals, Techniques, and Applications, 2nd edition, John Wiley and Sons, Inc., 2001.

BSi, Vocabulary – Nanoparticles, PAS 71:2005. Available for free download at: http://www.bsi-global.com/en/Standards-and-Publications/Industry-Sectors/Nanotechnologies/PAS-71/

Hinds, W.C., Aerosol Technology – Properties, Behavior, and Measurement of Airborne Particles, 2nd Edition, John Wiley and Sons, Inc., 1999.

ISO, Nanoparticles – Terminology and definitions, ISO/AWI TS 27687. Under development: http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

ISO, Workplace Atmospheres – Ultrafine, nanoparticle and nano-structured aerosols – Exposure characterization and assessment. Geneva: Switzerland: International Standards Organization. Document no. ISO/TR 27628, 2007. Available for purchase from ANSI, http://www.ansi.org/

NCI, Nanotechnology Glossary, http://nano.cancer.gov/resource_center/nanotech_glossary.asp

APPLICATIONS

There are over 400 commercial products using *engineered nanomaterials*, including self-cleaning windows (cars, homes), anti-graffiti paints, sunscreens, cosmetics, antimicrobial bandages, clothing, sports equipment, car components, etc. The Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars maintains a Nanotechnology Consumer Products Inventory that contains information on products that the center believes use some form of *nanotechnology*: http://www.nanotechproject.org/index.php?id=44 . The center also provides information regarding a myriad of existing and future applications for nanotechnology: http://www.nanotechproject.org/

The National Nanotechnology Initiative provides information regarding applications available today: http://www.nano.gov/html/facts/appsprod.html

Use of *engineered nanomaterials* will result in more effective medications, reduce the rate of infections in hospitals, diagnose diseases (such as cancer) at a much earlier stage and treat them more effectively and with substantially less side effects (e.g., as with some chemotherapeutic treatments), create longer lasting and more biocompatible artificial joints, make artificial tissues that replace diseased organs and repair nerve damage, etc.

- The National Nanotechnology Initiative (NNI) publication, Nanobiotechnology, describes applications in nanomedicine: http://www.nano.gov/nni_nanobiotechnology_rpt.pdf .

- The NNI provides links to NNI Centers, Networks, and Facilities describing applications and research and development of nanotechnology in the medical field: http://www.nano.gov/html/centers/nnicenters.html

- The National Cancer Institute (NCI) provides a site that explores nanotechnology in the fight against cancer and maintains a scientific bibliography on nanomedicine:
  http://nano.cancer.gov/resource_center/exploring.asp
  http://ncl.cancer.gov/working_ncl-nano.asp
  http://nano.cancer.gov/resource_center/scientific_bibliography.asp

- The National Institute of Health provides a site that containing information on (1) currently active NIH and Bioengineering Consortium research and training opportunities and (2) listings of funded grants for NIH and Bioengineering Consortium program announcements related to nanotechnology and nanoscience: http://www.becon.nih.gov/nano.htm

- A site maintained by Ion Channel Media provides information on recent high impact publications in nanomedicine and recent nanomedicine news: http://www.nano-biology.net/

● The Alliance for NanoHealth has collaborative research projects to address a multitude of medical issues, ranging from better drugs and more powerful diagnostic techniques to portable monitoring devices and smaller, more reliable implants, such as miniature, nanoscale, pacemakers: http://www.nanohealthalliance.org/

● Information on nanomedicine applications is available at the Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars: http://www.nanotechproject.org/114/nanofrontiers-visions-for-the-future-of-nanotechnology

Engineered nanomaterials may be used to prevent adverse effects to human health and environment by more effectively filtering the pollutants in our air and water, by reacting with toxic chemicals (e.g., at polluted sites) and making them less toxic, as well as enabling the use of cleaner energy sources which could result in less environmental pollution.

● The Meridian Institute presents applications for nanotechnology in water treatment: http://www.merid.org/nano/

● The U.S. Environmental Protection Agency Nanotechnology website and White Paper (February 2007) provide potential applications of nanomaterials:
http://es.epa.gov/ncer/nano/index.html
http://www.epa.gov/osa/pdfs/nanotech/epa-nanotechnology-white-paper-final-february-2007.pdf

● Information on green nanotechnology applications is available at the Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars:
http://www.nanotechproject.org/
http://www.nanotechproject.org/tags?tag=green

Engineered nanomaterials may make us less reliant on foreign oil and solve many of our energy problems, for instance, resulting in significantly more energy efficient vehicles, power transmission lines, and solar panels, as well as enabling the use of cleaner energy sources which could result in less environmental pollution. The NNI document, Nanoscience Research for Energy Needs describes potential applications: http://www.nano.gov/nni_energy_rpt.pdf

Computers will become smaller yet have significantly faster processing speeds and storage capacity. The Institute for Nanoelectronics and Computing provides relevant information in this area: http://www.inac.purdue.edu/

Personal protective equipment (e.g., respirators, clothing, etc.) will become lighter and more effective against harmful objects and substances, and in some cases, be able to detect, destroy, or otherwise actively respond to harmful substances.

Instruments used to detect harmful chemical, biological, and radiological materials in the air, water, and soil will become smaller, lighter, have faster response times, and detect concentrations at lower levels with greater accuracy and specificity.

The U.S. Federal government is investing heavily into applications research and development of *engineered nanomaterials*: http://www.nano.gov/NNI_07Budget.pdf
There are a number of government agencies and departments that are participating in the National Nanotechnology Initiative: http://www.nano.gov/html/gov/home_gov.html

ENVIRONMENT, HEALTH, AND SAFETY (EHS)
RESEARCH FINDINGS AND RESEARCH NEEDS

The Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars has developed an inventory that catalogs global government-funded research into the human health, safety and environmental implications of *nanotechnology*: http://www.nanotechproject.com/index.php?id=18

The International Council on Nanotechnology (ICON) provides an online database and journal regarding the scientific findings to-date related to the EHS benefits and risks of *nanomaterials*: http://icon.rice.edu/virtualjournal.cfm The NIOSH Nanoparticle Library is linked to the ICON database: http://www.cdc.gov/niosh/topics/nanotech/NIL.html

The National Institute for Occupational Health and Safety (NIOSH) is responsible for conducting research and making recommendations to prevent work-related injury, illness, and death. The NIOSH Nanotechnology Research website contains information specific activities that NIOSH is conducting in the field of nanotechnology, including identifying and controlling health and safety hazards of nanomaterials in the workplace: http://www.cdc.gov/niosh/topics/nanotech/research.html The NIOSH document "Progress Toward Safe Nanotechnology in the Workplace" (2007) is a report of the progress of the NIOSH Nanotechnology Research Center since its inception in 2004 through 2006: research describes NIOSH research efforts from hazard identification to risk management: http://www.cdc.gov/niosh/docs/2007-123/pdfs/2007-123.pdf

There are many unanswered questions with regard to the environmental, health, and safety implications of *engineered nanomaterials*, but for which only further research will adequately answer. To meet this need, the U.S. Federal government published a document in 2006 that identified EHS research needs related to the understanding and management of potential risks of engineered *nanoscale* materials that may be used, for example, in commercial or consumer products, medical treatments, environmental applications, and research: http://www.nano.gov/NNI_EHS_research_needs.pdf .

The U.S. Environmental Protection Agency (EPA) Nanotechnology White Paper (February 2007) includes the research needs they see for environmental applications and implications: http://www.epa.gov/osa/pdfs/nanotech/epa-nanotechnology-white-paper-final-february-2007.pdf

CHARACTERIZATION, ENVIRONMENT, SAFETY, AND HEALTH

Physical-Chemical Parameters that may be Toxicological Importance

Current research indicates that particle size, surface area, and surface chemistry (or activity) may be more important metrics than mass and bulk chemistry. A number of sources have indicated physical and chemical characteristics that may have important health implications. The toxicity and health risk may be a factor of the following properties, all or some of which may be significant, or not, and whereby some properties may enhance the overall toxicity. This list is subject to change.

(a) size and size distribution
(b) shape and shape distribution: e.g., fiber diameter, length, and aspect ratios for individual nanotubes and bundles/ropes.
(c) state of agglomeration, aggregation, and dispersion
(d) biopersistence/durability/solubility
(e) surface area: biologically available surface area, specific surface area, external (geometric surface area), and internal (if material is porous). Microporous or mesoporous powders exhibit much higher surface areas than nonporous powders.
(f) porosity
(g) surface chemistry: surface composition, surface energy/wettability, surface charge, surface reactivity, adsorbed species, and surface contamination.
(h) trace impurities/contaminants (e.g., metal catalysts, polycyclic aromatic hydrocarbons, etc.)
(i) chemical composition, including spatially averaged (bulk) and spatially resolved heterogeneous composition
(j) physical properties: e.g., density, hardness, conductivity, etc.
(k) crystal structure/crystallinity: e.g., amorphous or crystalline, crystalline form/phase/polymorph (e.g., rutile or anatase titanium dioxide, etc.)
(l) surface roughness

Borm, P. et. al., Research Strategies for Safety Evaluation of Nanomaterials, Part V: Role of Dissolution in Biological Fate and Effects of Nanoscale Particles, Toxicological Sciences 90(1), 23-32, 2006.

Donaldson K. et. al., "Carbon Nanotubes: A Review of Their Properties in Relation to Pulmonary Toxicology and Workplace Safety," Toxicological Sciences 92(1), 5-22, 2006.

Environmental Protection Agency Nanotechnology White Paper (February 2007), http://www.epa.gov/osa/pdfs/nanotech/epa-nanotechnology-white-paper-final-february-2007.pdf

National Institutes of Health, National Cancer Institute, Nanotechnology Characterization Laboratory, Assay Cascade Protocols, http://ncl.cancer.gov/working_assay-cascade.asp

Nel et. al., Toxic Potential of Materials at the Nanolevel, Science, Vol. 311, pp. 622-627, 3 February 2006.

National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, "Approaches to Safe Nanotechnology -- An Information Exchange with NIOSH," July 2006. Online Available: http://www.cdc.gov/niosh/topics/nanotech/safenano/

Oberdorster, et al., Principles for characterizing the potential human health effects from exposure to nanomaterials: elements of a screening strategy, Particle and Fibre Toxicology, 2:8, 2005, Online, Available: http://rsi.ilsi.org/Nanomaterial+Toxicity.htm

Powers, et. al., Research Strategies for Safety Evaluation of Nanomaterials. Part VI. Characterization of Nanoscale Particles for Toxicological Evaluation, Toxicological Sciences 90(2), 296-303, 2006.

Powers, et. al., Characterization of the size, shape, and state of dispersion of nanoparticles for toxicological studies, Nanotoxicology, 1:1, 42 – 51, March 2007. Available at: http://dx.doi.org/10.1080/17435390701314902

Note: The web links to the ASTM E56.02 Committee on Characterization and ISO TC 229 Nanotechnologies should be for regularly consulted for the latest developments related to documents relating to physical-chemical parameters that may be of toxicological importance.
http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851
http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

Characterization of Physical-Chemical Parameters

ASTM, WK9953 New Standard Practice for Measuring Diameter and Wall Thickness of Multi-wall Carbon Nanotubes (MWNT) Using Transmission Electron Microscopy Methods. Under development**:** http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851

ASTM, WK9952 New Standard Practice for Measuring Length and Thickness of Carbon Nanotubes Using Atomic Force Microscopy Methods. Under development:
http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851

ASTM, WK8705 New Measurement of particle size distribution of nanomaterials in suspension by Photon Correlation Spectroscopy (PCS). Under development:
http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851

ASTM, WK13577 New Standard Practice for Calculation of Mean Sizes/Diameters and Standard Deviations of Particle Size Distributions. Under development: http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851

ASTM, WK10417 New Standard Practice for the Preparation of Nanomaterial Samples for Characterization. Under development: http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851

ISO, Use of transmission electron microscopy (TEM) in single walled carbon nanotubes (SWCNTs), ISO/AWI TS 10797. Under development: http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

ISO, Scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDXA) in the characterization of single walled carbon nanotubes (SWCNTs), ISO/AWI TS 10798. Under development: http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

ISO, Workplace Atmospheres – Ultrafine, nanoparticle and nano-structured aerosols – Exposure characterization and assessment. Geneva: Switzerland: International Standards Organization. Document no. ISO/TR 27628, 2007. Available for purchase from ANSI, http://www.ansi.org/

National Institutes of Health, National Cancer Institute, Nanotechnology Characterization Laboratory, Assay Cascade: http://ncl.cancer.gov/assay_cascade.asp , http://ncl.cancer.gov/newsletter_vol_001.asp , http://ncl.cancer.gov/newsletter_vol_002.asp

NIST, Center for Nanoscale Science and Nanotechnology, http://physics.nist.gov/Divisions/Div841/Gp3/cnst_home.html

Oberdorster, et al., Principles for characterizing the potential human health effects from exposure to nanomaterials: elements of a screening strategy, Particle and Fibre Toxicology, 2:8, 2005, Online, Available: http://rsi.ilsi.org/Nanomaterial+Toxicity.htm

Powers, et. al., Research Strategies for Safety Evaluation of Nanomaterials. Part VI. Characterization of Nanoscale Particles for Toxicological Evaluation, Toxicological Sciences 90(2), 296-303, 2006.

Powers, et. al., Characterization of the size, shape, and state of dispersion of nanoparticles for toxicological studies Nanotoxicology, 1:1, 42 – 51, March 2007. Available at: http://www.informaworld.com/smpp/title~content=t716100760

Note: The web links to the ASTM E56.02 Committee on Characterization and ISO TC 229 Nanotechnologies should be for regularly consulted for the latest developments related to documents relating to characterizing physical-chemical parameters that may be of toxicological importance.

http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851
http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

Note: The International Conference on Nanotechnology: Occupational and Environmental Health & Safety, 4-7 December 2006, Cincinnati, OH, slide presentations are available online, and includes characterization presentations:
http://www.uc.edu/noehs/conference_program.asp.

Note: Working in concert with the National Institute of Standards and Technology (NIST) and the U.S. Food and Drug Administration (FDA), the National Cancer Institute (NCI) established the Nanotechnology Characterization Laboratory (NCL) to perform and standardize preclinical efficacy and toxicity testing of nanoparticles intended for cancer therapeutics and diagnostics. The NCL is a national resource and knowledge base for cancer researchers from academia, government and industry, facilitating the development and translation of nanoscale particles and devices for clinical applications. Organizations can have their *engineered nanomaterials* characterized by the NCL if the applications meet the required criteria. The NCL generally does not accept proposals for characterization of *nanomaterials* intended for application in areas other than cancer, but do consider other applications with regard to *nanomaterials* intended for medical applications within the human body. Cancer-related nanostrategies proposed to the NCL for characterization are ranked according to their projected impact on clinical cancer applications and/or furthering nanotechnology's compatibility with biological systems. Characterization includes physical and chemical characterization and in toxicity characterization (*in vitro* and in *vivo*). The NCL is working with ASTM and ISO to develop standardized protocols. At the request of NIH NCL, NIST is preparing gold colloid reference materials (not standard reference materials, which take much longer) of 10 nm, 30 nm, and 80 nm sizes, which correspond to three biological barriers : 10 nm (kidney filtration), 30 nm (endothelial pores), and 80 nm (liver bile duct filtration); filtration barrier sizes are not absolute, e.g., with regard to liver filtration, pore sizes are 150-200 nm and bile duct (where clearance takes place) is about 80-100 nm.

Toxicological assessment

ASTM, WK8997 New Standard Practice for Analysis of Hemolytic Properties of Nanoparticles. Under development: **http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851**

ASTM, WK9326 New Standard Practice for Evaluation of the Effect of Nanoparticulate Materials on the Formation of Mouse Granulocyte-Macrophage Colonies. Under development: http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851

ASTM, WK9327 New Standard Practice for Evaluation of Cytotoxicity of Nanoparticulate Materials on Porcine Kidney Cells. Under development:
http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851

ISO, Nanotechnologies -- Generation of silver nanoparticles for inhalation toxicity testing, ISO/AWI 10801. Under development:
http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

ISO, Nanotechnologies -- Monitoring silver nanoparticles in inhalation exposure chambers for inhalation toxicity testing. Under development:
http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

ISO, Nanotechnologies -- Endotoxin test on nanomaterial samples for in vitro systems. Under development: http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

Klaus, U. et. al., Cellular responses to nanoparticles: Target structures and mechanisms, Nanotoxicology, 1:1, 52 – 71, March 2007. Available at:
http://www.informaworld.com/smpp/title~content=t716100760

National Institutes of Health, National Cancer Institute, Nanotechnology Characterization Laboratory, Assay Cascade: http://ncl.cancer.gov/assay_cascade.asp , http://ncl.cancer.gov/newsletter_vol_001.asp , http://ncl.cancer.gov/newsletter_vol_002.asp

Nel et. al., Toxic Potential of Materials at the Nanolevel, Science, Vol. 311, pp. 622-627, 3 February 2006.

Oberdorster et. al., Principles for characterizing the potential human health effects from exposures to nanomaterials: elements of a screening strategy, Particle and Fibre Toxicology, 2005, 2:8, http://rsi.ilsi.org/

Oberdorster et. al., Toxicology of nanoparticles: A historical perspective, Nanotoxicology, 1:1, 2 – 25, March 2007.
Available at: http://www.informaworld.com/smpp/title~content=t716100760

Note: There exists a battery of validated toxicity and ecotoxicity tests for chemicals, however much work is required to optimize these for *nanomaterials* that are often poorly understood in terms of their behavior in living organisms and in soil and water (Oberdorster et. al., p. 20, 2007). Special consideration will need to be given to the way in which particles are prepared in order to generate a relevant protocol (Oberdorster et. al., p. 20, 2007; Powers, et. al., 2007). Until standardized, well characterized, and relevant and validated protocols are in place, it will be difficult to interpret toxicity studies and compare results between laboratories (Oberdorster et. al., p. 20, 2007). Also, essential is the use of standard reference materials to compare behavior (e.g., titanium dioxide, carbon black, quartz, etc.) (Nel, 2006).

Note: The ASTM and ISO links should be for regularly consulted for developments related to toxicological assessment.

Note: The web links to the ASTM E56.02 Committee on Characterization and ISO TC 229 Nanotechnologies should be for regularly consulted for the latest developments related to toxicological assessment:
http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5602.htm?L+mystore+cprk8709+1177002851
http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

Note: The OECD link for Safety of Manufactured Nanomaterials should be regularly consulted: http://www.oecd.org/department/0,2688,en_2649_37015404_1_1_1_1_1,00.html . It is conceivable that there may be an effort to adapt some of the existing OECD Guidelines for the Testing of Chemicals to assess the toxicity of nanomaterials:
http://www.oecd.org/document/40/0,2340,en_2649_34377_37051368_1_1_1_1,00.html

Note: Working in concert with the National Institute of Standards and Technology (NIST) and the U.S. Food and Drug Administration (FDA), the National Cancer Institute (NCI) established the Nanotechnology Characterization Laboratory (NCL) to perform and standardize preclinical efficacy and toxicity testing of nanoparticles intended for cancer therapeutics and diagnostics. The NCL is a national resource and knowledge base for cancer researchers from academia, government and industry, facilitating the development and translation of nanoscale particles and devices for clinical applications. Organizations can have their *engineered nanomaterials* characterized if the applications meet the required criteria. The NCL generally does not accept proposals for characterization of nanomaterials intended for application in areas other than cancer, but do consider other applications with regard to nanomaterials intended for medical applications within the human body. Cancer-related nanostrategies proposed to the NCL for characterization are ranked according to their projected impact on clinical cancer applications and/or furthering nanotechnology's compatibility with biological systems. Characterization includes physical and chemical characterization and in toxicity characterization (*in vitro* and in *vivo*). The NCL is working with ASTM and ISO to develop standardized protocols. At the request of NIH NCL, NIST is preparing gold colloid reference materials (not standard reference materials, which take much longer) of 10 nm, 30 nm, and 80 nm sizes, which correspond to three biological barriers : 10 nm (kidney filtration), 30 nm (endothelial pores), and 80 nm (liver bile duct filtration); filtration barrier sizes are not absolute, e.g., with regard to liver filtration, pore sizes are 150-200 nm and bile duct (where clearance takes place) is about 80-100 nm.

Note: The International Conference on Nanotechnology: Occupational and Environmental Health & Safety, 4-7 December 2006, Cincinnati, OH, slide presentations are available online, and includes toxicology presentations:
http://www.uc.edu/noehs/conference_program.asp.

Occupational Health and Safety

ASTM, WK8985 New Standard Guide for Handling Unbound Engineered Nanoparticles in Occupational Settings. Under development: http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/SUBCOMMIT/E5603.htm?L+mystore+cprk8709+1177117315

ICON, Online EHS journal and database: http://icon.rice.edu/virtualjournal.cfm

International Conference on Nanotechnology: Occupational and Environmental Health & Safety, 4-7 December 2006, Cincinnati, OH. Slide presentations online, available: http://www.uc.edu/noehs/conference_program.asp.

ISO, Workplace Atmospheres – Ultrafine, nanoparticle and nano-structured aerosols – Exposure characterization and assessment. Geneva: Switzerland: International Standards Organization. Document no. ISO/TR 27628, 2007. Available for purchase from ANSI, http://www.ansi.org/

Maynard, A.D. and Aitken, R.J., Assessing exposure to airborne nanomaterials: Current abilities and future requirements, Nanotoxicology, Volume 1:1, 26-41, March 2007. Available at: http://www.informaworld.com/smpp/title~content=t716100760

NIOSH, Approaches to Safe Nanotechnology -- An Information Exchange with NIOSH. Available at: http://www.cdc.gov/niosh/topics/nanotech/safenano/

NIOSH, Progress Toward Safe Nanotechnology in the Workplace, February 2007. Available at: http://www.cdc.gov/niosh/docs/2007-123/pdfs/2007-123.pdf

NIOSH, Nanoparticle Information Library: http://www.cdc.gov/niosh/topics/nanotech/NIL.html

NIOSH, Evaluation of Health Hazard and Recommendations for Occupational Exposure to Titanium Dioxide, DRAFT Current Intelligence Bulletin" Online, available: http://www.cdc.gov/niosh/review/public/TIo2/

Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars, Health and Environmental Implications: an inventory of current research: http://www.nanotechproject.com/index.php?id=18

Note: The NIOSH, ASTM, ISO, and OSHA links should be regularly consulted for the latest developments related to occupational health and safety.

Occupational Medical Surveillance

NIOSH, Trout, D., NIOSH Medical Officer, Medical Evaluations and Worker Health, International Conference on Nanotechnology: Occupational and Environmental Health & Safety, 4-7 December 2006, Cincinnati, OH. Slide presentation online, available: http://www.uc.edu/noehs/conference_program.asp.

Note: NIOSH will be developing medical surveillance guidelines in collaboration with other federal agencies, industry, and other interested parties. Consult the NIOSH Nanotechnology hompage regularly for developments: http://www.cdc.gov/niosh/topics/nanotech/default.html

NIOSH, NTRC Epidemiology and Surveillance Projects (IN: Progress Toward Safe Nanotechnology in the Workplace, February 2007, pp. 24-25). Available at: http://www.cdc.gov/niosh/docs/2007-123/pdfs/2007-123.pdf

NIOSH, NTRC Epidemiology and Surveillance Projects (IN: Progress Toward Safe Nanotechnology in the Workplace (2007) is a report of the progress of the NIOSH Nanotechnology Research Center since its inception in 2004 through 2006: research describes NIOSH research efforts from hazard identification to risk management: http://www.cdc.gov/niosh/docs/2007-123/pdfs/2007-123.pdf

Occupational Exposure Registries (IN: EHS research needs for Engineered nanoscale materials, p. 37, http://www.nano.gov/NNI_EHS_research_needs.pdf)

Environmental Protection

EPA, Nanotechnology White Paper, February 2007: http://www.epa.gov/osa/pdfs/nanotech/epa-nanotechnology-white-paper-final-february-2007.pdf

EPA Nanotechnology Website: http://es.epa.gov/ncer/nano/

Lifecycle EHS Risk Management

Environmental Defense-DuPont, Nano Risk Framework (DRAFT): http://www.nanoriskframework.com/page.cfm?tagID=1095

Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars, Nanotechnology and Life Cycle Assessment – A Systems Approach to Nanotechnology and the Environment: http://www.nanotechproject.org/111/32007-life-cycle-assessment-essential-to-nanotech-commercial-development

WEBSITES

American Industrial Hygiene Association (AIHA): http://www.aiha.org/Content/Topics/nano/

ASTM E56 Nanotechnologies:
http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/COMMITTEE/E56.htm?L+mystore+cprk8709+1179181259

Environmental Protection Agency (EPA): http://es.epa.gov/ncer/nano/

Food and Drug Administration (FDA): http://www.fda.gov/nanotechnology/

International Conference on Nanotechnology: Occupational and Environmental Health & Safety, 4-7 December 2006, Cincinnati, OH. Slide presentations online, available:
http://www.uc.edu/noehs/conference_program.asp.

International Council on Nanotechnology (ICON):
http://cohesion.rice.edu/centersandinst/cben/industry.cfm?doc_id=5023

International Organization for Standardization (ISO) TC 229 Nanotechnologies:
http://www.iso.org/iso/en/CatalogueListPage.CatalogueList?COMMID=5932&scopelist=PROGRAMME

National Cancer Institute (NCI): http://nano.cancer.gov/

National Institute for Occupational Safety and Health (NIOSH):
http://www.cdc.gov/niosh/topics/nanotech/

National Nanotechnology Initiative (NNI): http://www.nano.gov/

Occupational Safety and Health Administration (OSHA): http://www.osha.gov/

Organisation for Economic Co-operation and Development (OECD):
http://www.oecd.org/department/0,2688,en_2649_37015404_1_1_1_1_1,00.html

Woodrow Wilson International Center for Scholars, Project on Emerging Nanotechnologies: http://www.nanotechproject.org/

ABBREVIATIONS AND ACRONYMS

AIHA: American Industrial Hygiene Association

DOE: Department of Energy

EHS: Environment, health, and safety

EPA: Environmental Protection Agency

FDA: Food and Drug Administration

g/cc: grams per cubic centimeter

ICON: International Council on Nanotechnology

ISO: International Organization for Standardization

mg/m^3: milligrams per cubic meter

mm: millimeter

MURI: Multi-disciplinary University Research Initiative

NASA: National and Aeronautics Space Administration

NCI: National Cancer Institute

NCL: Nanotechnology Characterization Laboratory

NIOSH: National Institute for Occupational Safety and Health

NIST: National Institute of Standards and Technology

nm: nanometers

NNI: National Nanotechnology Initiative

OECD: Organisation for Economic Co-operation and Development

OSHA: Occupational Safety and Health Administration

PM: particulate matter

μm: micrometers