Nanotechnology: Safety and Risk Management Overview

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Overview

- Risk perception: Why all the “buzz” about nanotechnology safety and risk?
- Human health and environmental concerns
- Assessing, managing and communicating “risk”

EH&S Risk Management Categories

- Health Decrement (Injury and Illness Prevention)
- Regulatory Liability (Environmental and Occupational Compliance Risk)
- Adverse Public Relations
- Operational Impact to University Mission (casualty loss)
- General Liability (Third party lawsuits)

Ten Toxic Warnings

1. 1997 - ***Titanium dioxide/zinc oxide*** nanoparticles from sunscreen are found to cause free radicals in skin cells, damaging DNA. (Oxford University and Montreal University) Dunford, Salinaro et al.
2. March 2002 – „… ***engineered nanoparticles*** accumulate in the organs of lab animals and are taken up by cells…“ Dr. Mark Wiesner
3. March 2003 - „.. studies on effects of ***nanotubes*** on the lungs of rats produced more toxic response than quartz dust.“ „Scientists from DuPont Haskell laboratory present varying but still worrying findings on nanotube toxicity. Nanotubes can be highly toxic." - Dr. Robert Hunter (NASA researcher)
4. March 2003 - Dr. Howard: the smaller the particle, the higher its likely toxicity and that ***nanoparticles*** have various routes into the body and across membranes such as the blood brain barrier. ETC Group
5. July 2003 - Nature reports on work by CBEN scientist Mason Tomson that shows ***buckyballs*** can travel unhindered through the soil. "Unpublished studies by the team show that the nanoparticles could easily be absorbed by earthworms, possibly allowing them to move up the food-chain and reach humans" - Dr. Vicki Colvin, the Center's director.

Source: etcgroup.org 1 April, 2004

Ten Toxic Warnings

6. January 2004 - Dr. Günter Oberdörster: ***nanoparticles*** are able to move easily from the nasal passageway to the brain.

7. January 2004 - Nanosafety researchers from University of Leuven, Belgium in Nature: ***nanoparticles*** will require new toxicity tests: "We consider that producers of nanomaterials have a duty to provide relevant toxicity test results for any new material, according to prevailing international guidelines on risk assessment. Peter H. M. Hoet, Abderrrahim Nemmar and Benoit Nemery, University of Belgium(14)

8. January 2004 - Nanotox 2004: Dr. Vyvyan Howard presents initial findings that ***gold nanoparticles*** can move across the placenta from mother to fetus.

9. February 2004 - Scientists at University of California, San Diego discover that ***cadmium selenide nanoparticles*** (quantum dots) can break down in the human body potentially causing cadmium poisoning. "This is probably something the [research] community doesn't want to hear." - Mike Sailor, UC San Diego.(16)

10. March 2004 - Dr. Eva Oberdörster: ***buckyballs (fullerenes)*** cause brain damage in juvenile fish along with changes in gene function. "Given the rapid onset of brain damage, it is important to further test and assess the risks and benefits of this new technology before use becomes even more widespread." - Dr. Eva Oberdörster.

Source: etcgroup.org 1 April, 2004

Toxicological concerns

As the 10 toxic warnings show, nanoparticles may have physiological effects that their bulk counterparts lack:

- They may cross the blood-brain barrier
- They may cross the placental barrier
- They may have electronic effects that short-circuit metabolic processes in the cell

On The One hand, Nanoparticles Are Not a Recent Discovery

- Particles in the nanometer size range have existed for many years.
- Some of these materials, even with exposures of nano-size particles, have not exhibited toxic health effects.

On the Other Hand:
We also know a lot about pulmonary toxicity of some small particles and fibers in humans

- Toxicity of particles and fibers
  - Quartz
    - Related to surface area and surface activity
  - Asbestos
    - Particle length and diameter
    - Surface activity and durability
  - Air pollution
    - Toxic responses to apparently non-toxic substances when exposed in sufficient dose in nano-size range
  - Medical applications

But what is DIFFERENT about NANO-sized particles?

- Total surface area is larger
- Chemical reactivity is higher
- Smaller size facilitates cellular/organ uptake
- Tendency to agglomerate
- They may be more persistent (less biodegradable)

Nanoscale particles must have distinctly different properties than their larger counterparts -- otherwise, they wouldn't be so interesting to us…

And why should we care about nanoparticle/nanotechnology safety?

- Personal safety
- Effect on the environment
- Health and safety of workers in nanomanufacturing
- Health and safety of consumers

If we do not address these concerns early on, backlash will result in stricter laws and less funding for research and capital investment.

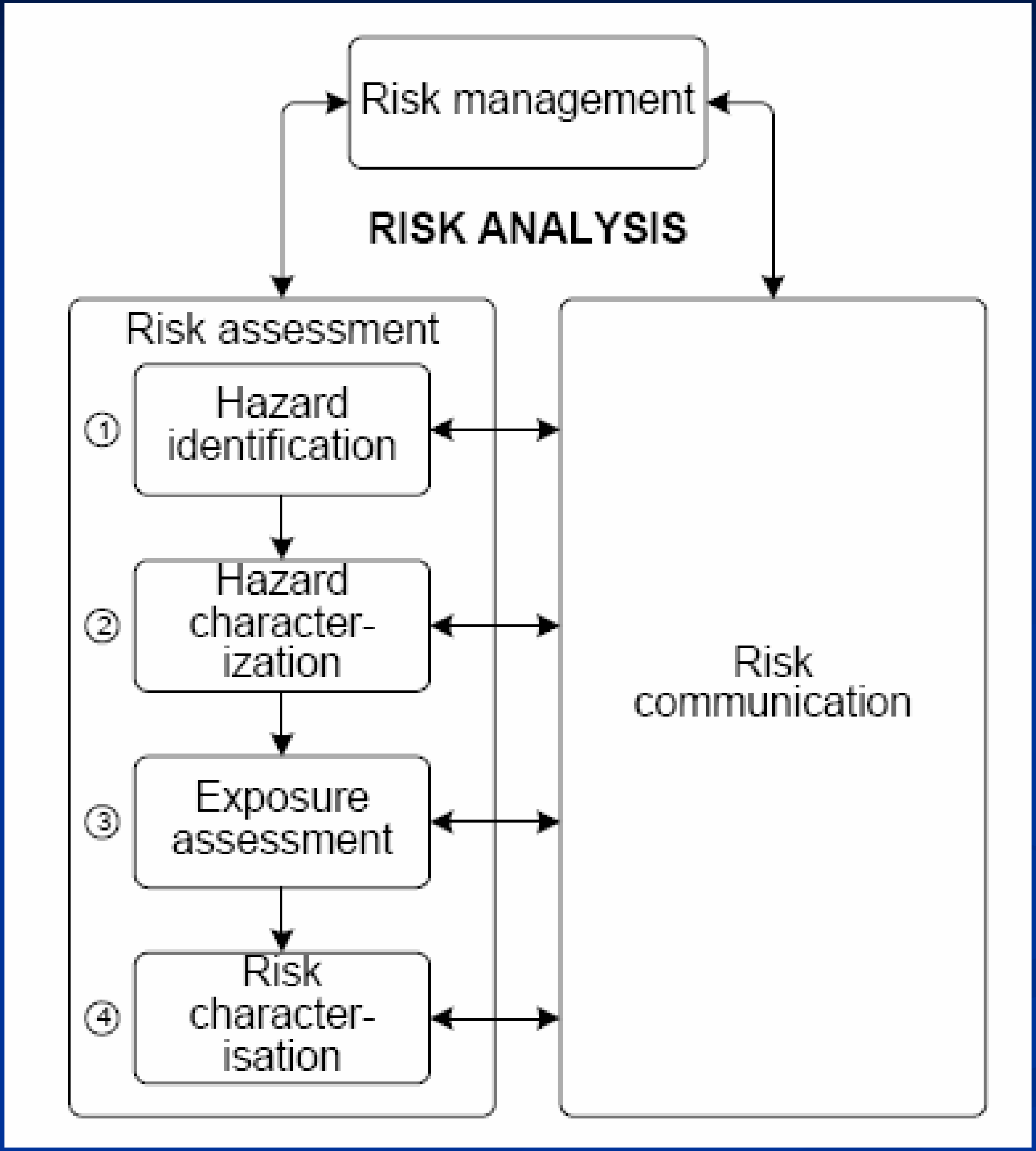
Investors, Industrialists, Scientists

- Venture capitol firm Draper Fisher Jurvetson: "It would not invest in a nanotech business unless the products had already been proven safe."

- Germany-based Munich Re Group: "Up to now, losses involving dangerous products were on a relatively manageable scale, whereas, taken to extremes, nanotechnology products can even cause ecological damage which is difficult to contain."

http://www.smalltimes.com/document_display.cfm?document_id=7608

The three interconnected components of risk analysis—risk assessment, risk management, and risk communication



European Commission Report 2004

Basic Quantifiable Risk Variables

- Hazard: potential to cause harm (toxicity, likelihood of explosion)
- Exposure: concentration of substance in a relevant medium multiplied by the duration of contact
- Dose: amount of substance that will reach a specific biological system
- Risk: quantification of likelihood of harm occurring

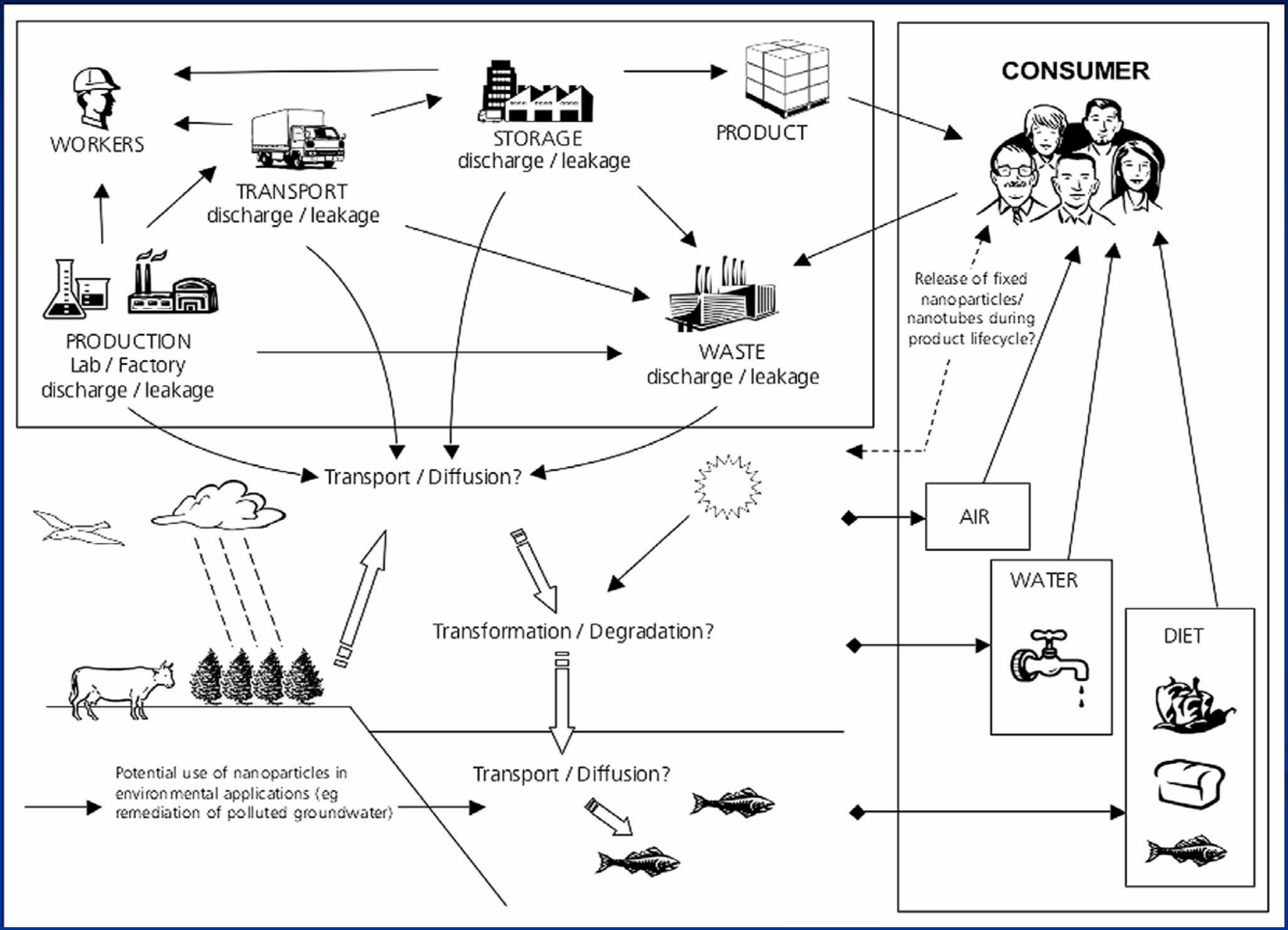
Identifying and Quantifying Hazards

- Physical hazards
  - Energy (electrical, chemical reactions, fire/explosion, etc)
- Health hazard risk = *f* (toxicity, dose)
  - Toxicity: inherent property of substance
  - Dose: amount of material actually taken into/on body

"Dosis facit venenum" (*"The dose makes the poison."*)

Paracelsus (1493-1541)

Possible Routes of Exposure: Inhalation; Dermal Contact; Ingestion; Injection



Royal Society Report July 2004

Environmental Exposure Concerns for Nanoparticles

- Routes of exposure
  - Nanoparticles are easily airborne
  - Adhere easily to surfaces
  - Difficult to detect
- Intrinsic properties may elevate risk
  - Persistence
  - Bioaccumulation
  - Toxicity

Pulmonary nanotoxicology

Most all nanotoxicology focuses on pulmonary effects of nanoparticulates. Little attention is given to:

- Alternate routes of exposure to nanoparticles
- Impact of nanomaterials on the natural environment (air, water, biota)
- Other non-particle risk factors associated with nanotech and nanomanufacturing

Other potential risks of nanotechnology

- Nanoparticles in the environment may:
  - Enter the food chain
  - Influence the biosphere
  - Influence structural transition by liquids like water (biogenic nanoparticles)
  - Chemical/physical transition by recycling (combustion)
- Nanomanufacturing will create new kinds and new classes of chemical waste streams
- New, previously unconsidered, hazards may appear as different disciplines merge

Controlling Risk

To control risk, it is the responsibility of the nanotechnology professional to understand the potential hazards of the materials and processes involved by:

- Reducing hazardous properties
  - Substitute less hazardous substance for more hazardous where possible
- Reducing probability of exposure
  - Engineering and procedural controls to limit worker exposure
  - Limit release of material to environment
  - Interrupt pathways to a receptor

Risk: An Amended Perspective

- Quantitative

  Risk (Hazard) = *f* (toxicity, dose)

- Qualitative
  - ”A threat to that which we <u>value</u>.”
  - “The probability of loss of that which we <u>value</u>.”

Risk = Hazard + Outrage

- Hazard – technical component of risk, the product of probability and magnitude
- Outrage – non-technical component, a mix of voluntariness, control, responsiveness, trust, dread, etc., connected by the fact that outrage is the principle determinant of perceived risk

Twelve Principal Outrage Components

"Safe"	**"Risky"**
1. Voluntary	Coerced
2. Natural	Industrial
3. Familiar	Exotic
4. Not memorable	Memorable
5. Not dreaded	Dreaded
6. Chronic	Catastrophic
7. Knowable	Unknowable
8. Individually controlled	Controlled by others
9. Fair	Unfair
10. Morally irrelevant	Morally relevant
11. Trustworthy sources	Untrustworthy sources
12. Responsive process	Unresponsive process

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Kinds of Risk Communication

- Public Relations: High Hazard, Low Outrage
- Stakeholder Relations: Moderate Hazard, Moderate Outrage
- Outrage Management: Low Hazard, High Outrage
- Crisis Communication: High Hazard, High Outrage

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Explaining Environmental Risk: Dealing with the Public

- Risk perception is a lot more than mortality statistics
- Moral categories mean more than risk data
- Policy decisions are seen as either risky or safe
- Equity and control issues underlie most risk controversies
- Risk decisions are better when the public shares the power
- Explaining risk information is difficult but not impossible
- Risk communication is easier when emotions are viewed as legitimate

What Scientists Need to Know about Communicating Risk to the Public

- That normal people's response to risk is emotional and "rational" (cognitive) at the same time.
- That you can't give people scary information without scaring them.
- That people are usually able to tolerate anxiety and even fear, without escalating into terror or panic.
- That risk communication professionals have evolved techniques for helping people do so.
- That demanding that people stay unemotional about risk isn't one of the techniques that work.

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What Scientists Need to Know about Communicating Risk to the Public

- That demanding that the media suppress alarming content also isn't one of the techniques that work.
- That those who want to educate the public should first study how the public learns.
- That all of the above generalizations are supported by data.
- That scientists who ignore such data and decry "irrationality" — that is, emotionality — in society's response to risk are acting out of their own emotions, compounded by ignorance and arrogance.

Risk decisions are better when the public shares the power

- When citizens participate in a risk management decision they are far more likely to accept it
  - They have instituted change that make it morally more acceptable
  - They have learned why the experts consider the risk acceptable
  - They have been heard and not excluded

Rules for popularizing technical content

- Tell people what you have determined they ought to know
- Add what people must know in order to understand and *feel* that they understand the information
- Add enough qualifiers and structural guidelines to prepare people for what you are not telling them

Application to the research bench?

- Be aware of potential risks in nanotechnology research laboratories
- Consider possible life-cycle risk issues, from development of new technologies to ultimate disposition of materials.
- Understand elements of risk and concern in developing new products for use in society

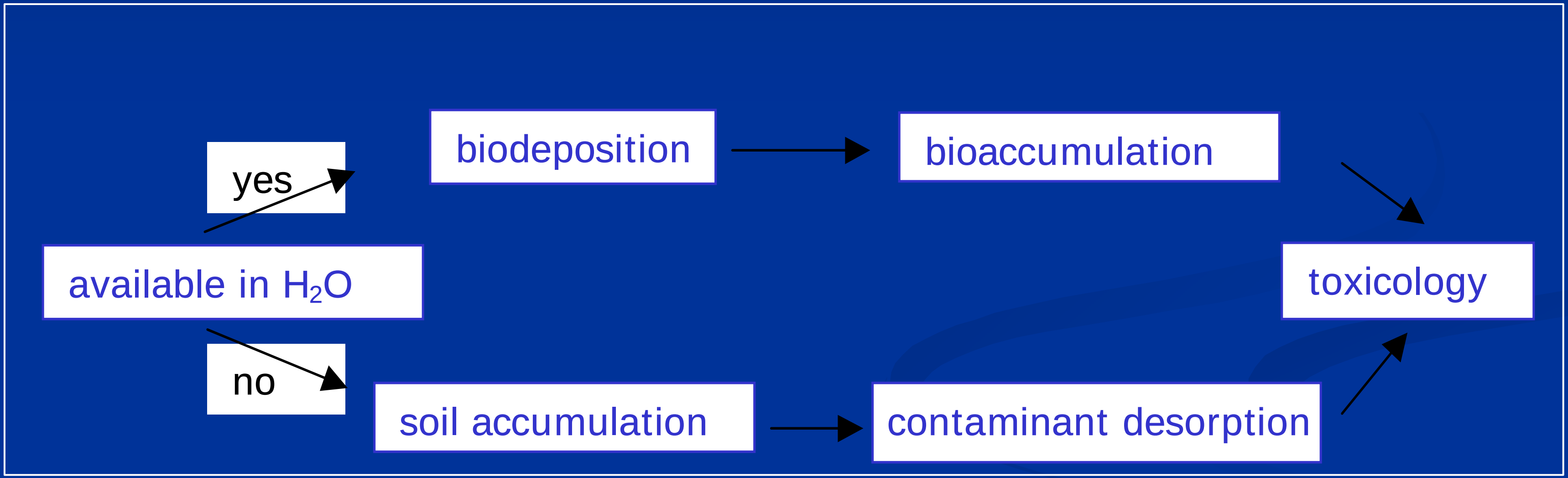
Personnel Risks in Nanotechnology Research

Example: fabrication research facility

- Process (research) personnel
  - Solvents, oxidizers, HF, corrosives, toxic gases, reactors, furnaces, etc.
- Research tools and maintenance personnel
  - Lab chemicals, shop chemicals, product residue on tools, energy sources
- Dock and support personnel
  - Chemical container handling, forklift operations
- Facilities (infrastructure support)personnel
  - Corrosives, oils, lubricants, manual material handling
- Growing concern: Use of nanotechnology research and development tools by researchers from other disciplines (biosciences, engineering, etc.)

Assessing the toxicological risks of nanotechnology

Initial assessment of risk potentials in ongoing
and future R&D-projects:



Proposal for a short-test route
as a prerequisite for R&D projects

TOP NANO 21, Lucerne April 2004

Summary

- Identify and understand the potential risks associated with nanotechnology and nanotech products - Do this EARLY on.
- Assure clear and balanced communication between potential risks and benefits
- Educate and involve all stakeholders early in development of policy and regulation
- Begin by clearly identifying and evaluating risks associated with nanotechnology research activities, operations and products

References

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