Nanotechnology: Identifying and Managing EH&S Risks

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Overview

- Nanotechnology EH&S risks: real and perceived
- Assessing, managing and communicating on “risks”
- Recommendations to address identified “risks”

EH&S Role in Managing Risks

- Health Decrement
- Regulatory Liability
- Operational Impact to Organizational Mission
- Adverse Public Relations
- General/Product Liability/Lawsuits

Introduction of the General Public to New Technologies

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Need for Better Understanding of Nanotechnology EH&S Risks

- 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

- Swiss Re: "Only those who have a clear picture of the risk landscape can be reliable partners in the risk business itself."

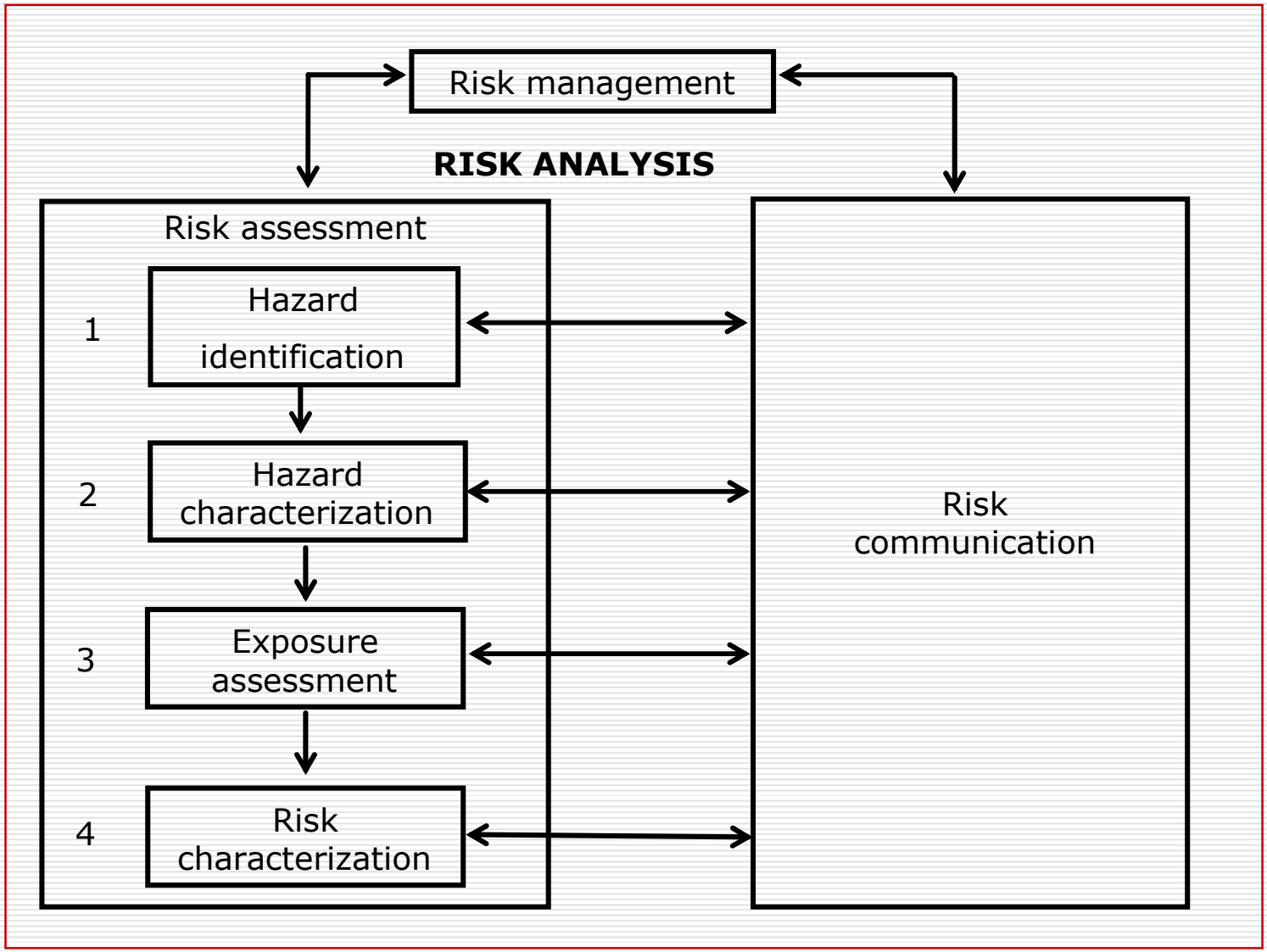
Nanotechnology: Small matter, many unknowns, Swiss Re 2004 (www.SwissRe.com)

And why should we care about nanotechnology EH&S risks?

- Health and safety of workers in nano-manufacturing
- Health and safety of consumers
- Health of the environment
- Public backlash could paint the entire nanotechnology landscape

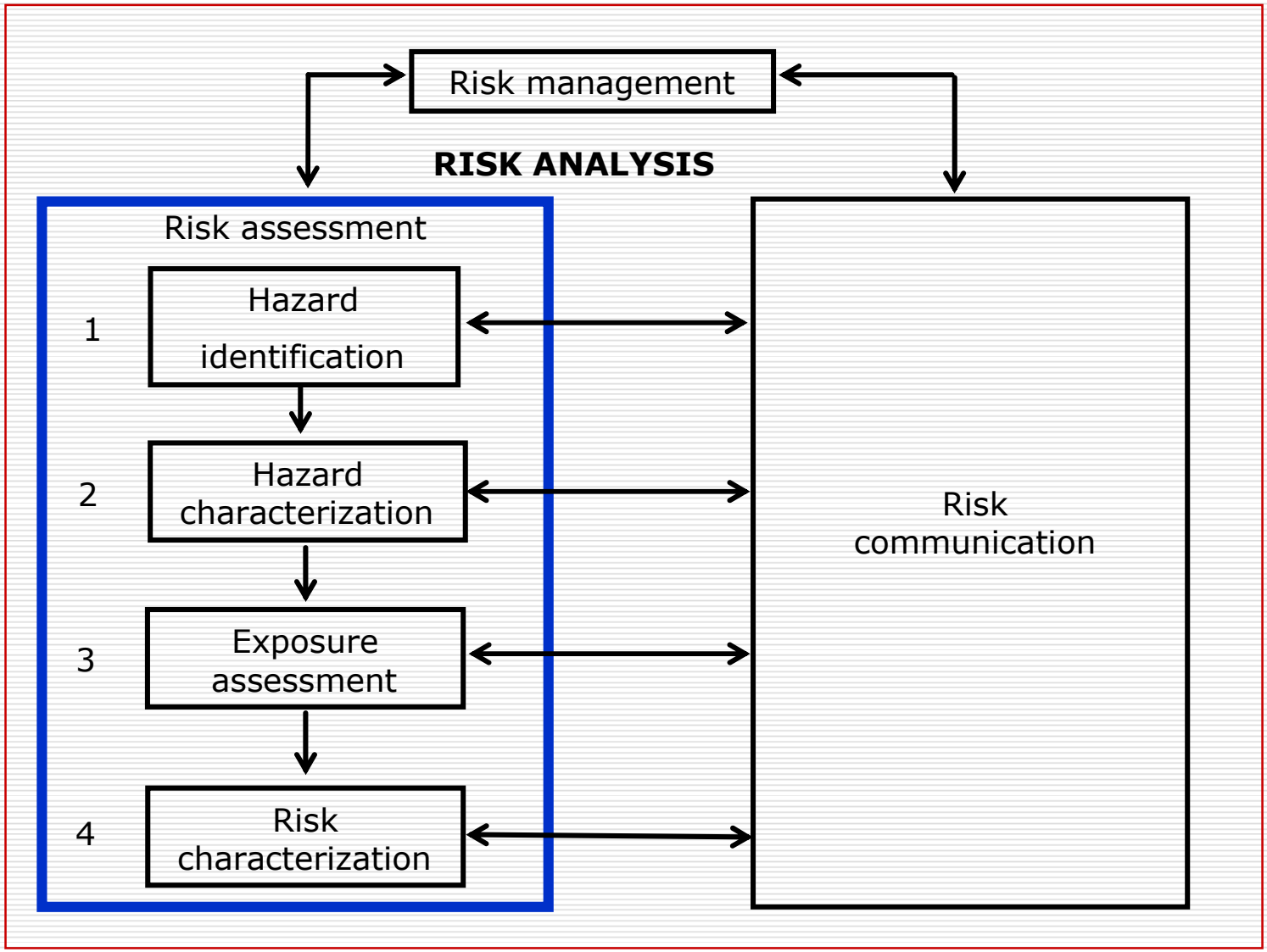
So, where do we go from here?

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



European Commission Report 2004

Traditional Risk assessment: 4 Step process



European Commission Report 2004

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.(8)
2. March 2002 – Researchers from the Center for Biological and Environmental Nanotechnology (CBEN, Rice University, Houston) report to US EPA that engineered **nanoparticles** accumulate in the organs of lab animals and are taken up by cells. "We know that nanomaterials have been taken up by cells. That sets off alarms. If bacteria can take them up then we have an entry point for nanomaterials into the food chain." – Dr. Mark Wiesner(9)
3. March 2003 – Researchers from NASA/Johnson Space Center report that 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. "The message is clear. People should take precautions. Nanotubes can be highly toxic." – Dr. Robert Hunter (NASA researcher)(10)
4. March 2003 – ETC group publishes first scientific literature survey on **nanoparticle toxicity** by toxicopathologist Vyvyan Howard. Dr. Howard concludes that 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. "Full hazard assessments should be performed to establish the safety of species of particle before manufacturing is licensed. We are dealing with a potentially hazardous process." – Dr. Vyvyan Howard(11)
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(12)

Source: http://www.etcgroup.org/article.asp?newsid=445

Ten Toxic Warnings

6. 6 January 2004 – Research by Dr. Günter Oberdörster is published showing that **nanoparticles** are able to move easily from the nasal passageway to the brain. "The nanotechnology revolution may design particles that are very different chemically from the ones we are exposed to, and they might have very different properties that made them more harmful. We should be vigilant." – Professor Ken Donaldson, University of Edinburgh(13)
7. 7 January 2004 – Nanosafety researchers from University of Leuven, Belgium, write in Nature that **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. Even some 'old' chemical agents may need to be reassessed if their physical state is substantially different from that which existed when they were assessed initially."– Peter H. M. Hoet, Abderrahim Nemmar and Benoit Nemery, University of Belgium (14)
8. 8 January 2004 – At the first scientific conference on nanotoxicity, Nanotox 2004, Dr. Vyvyan Howard presents initial findings that **gold nanoparticles** can move across the placenta from mother to fetus.(15)
9. 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. 10 March 2004 – Dr. Eva Oberdörster reports to American Chemical Society meeting that **buckyballs** cause brain damage in juvenile fish along with changes in gene function. They also are toxic to small crustaceans (water fleas). "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.(17)

Source: http://www.etcgroup.org/article.asp?newsid=445

Toxicological concerns

As the 10 toxic warnings illustrate, **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

Nanoparticles Are Not a Recent Discovery

- Particles in the nanometer size range have existed for many years.
  - volcanic emissions
  - forest fires
  - products of combustion
  - soot

We also know a lot about pulmonary toxicity of some small particles and fibers in humans

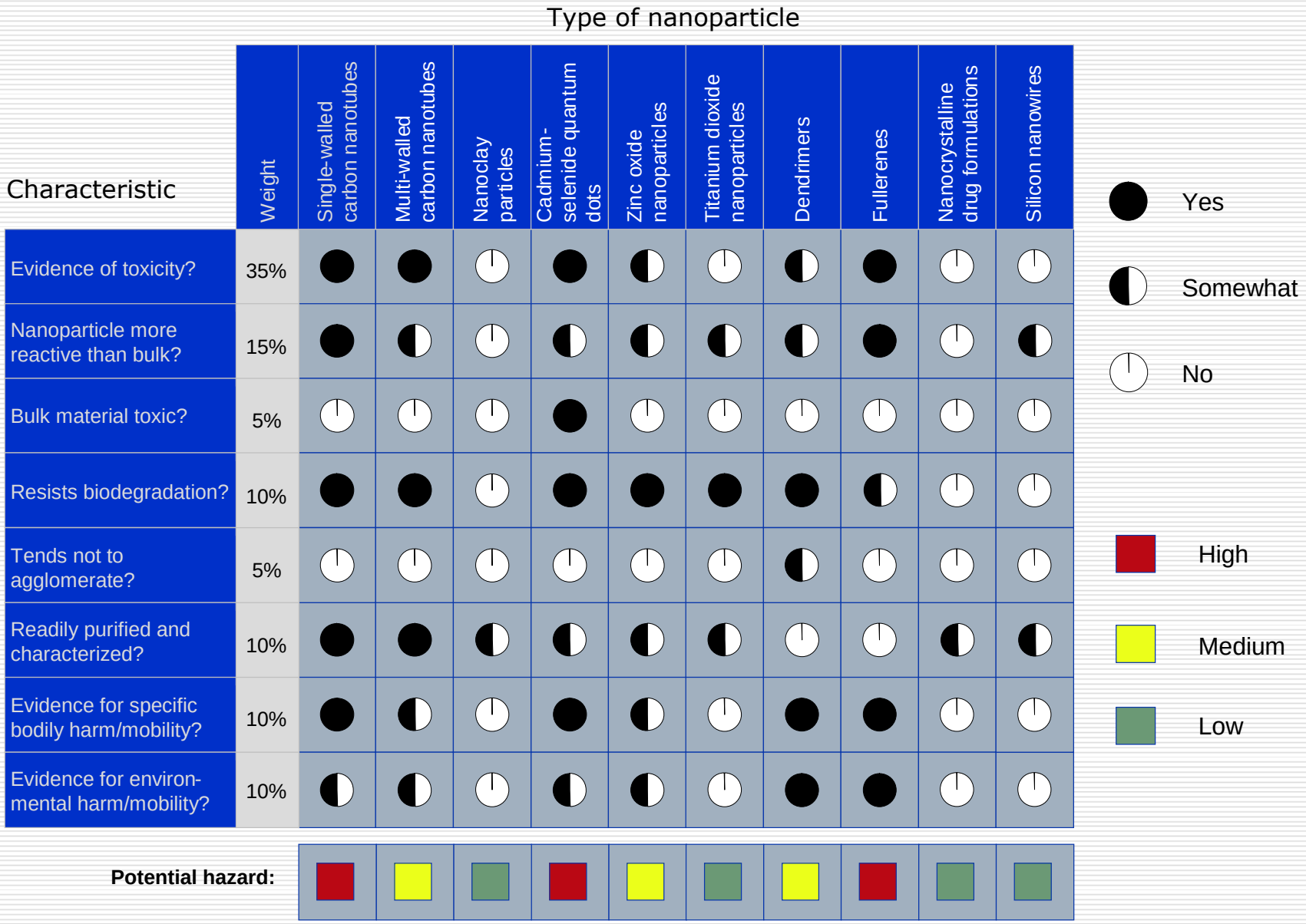
- Quartz
  - Related to surface area and surface activity
- Asbestos
  - Particle length and diameter
  - Surface activity and durability
- Air pollution
  - Toxic responses to apparently non-toxic substances when exposed in sufficient dose in nano-size range
- Medical applications

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)
- Additional influence of exotic/unique properties
- Synergistic effects from composite materials and structures

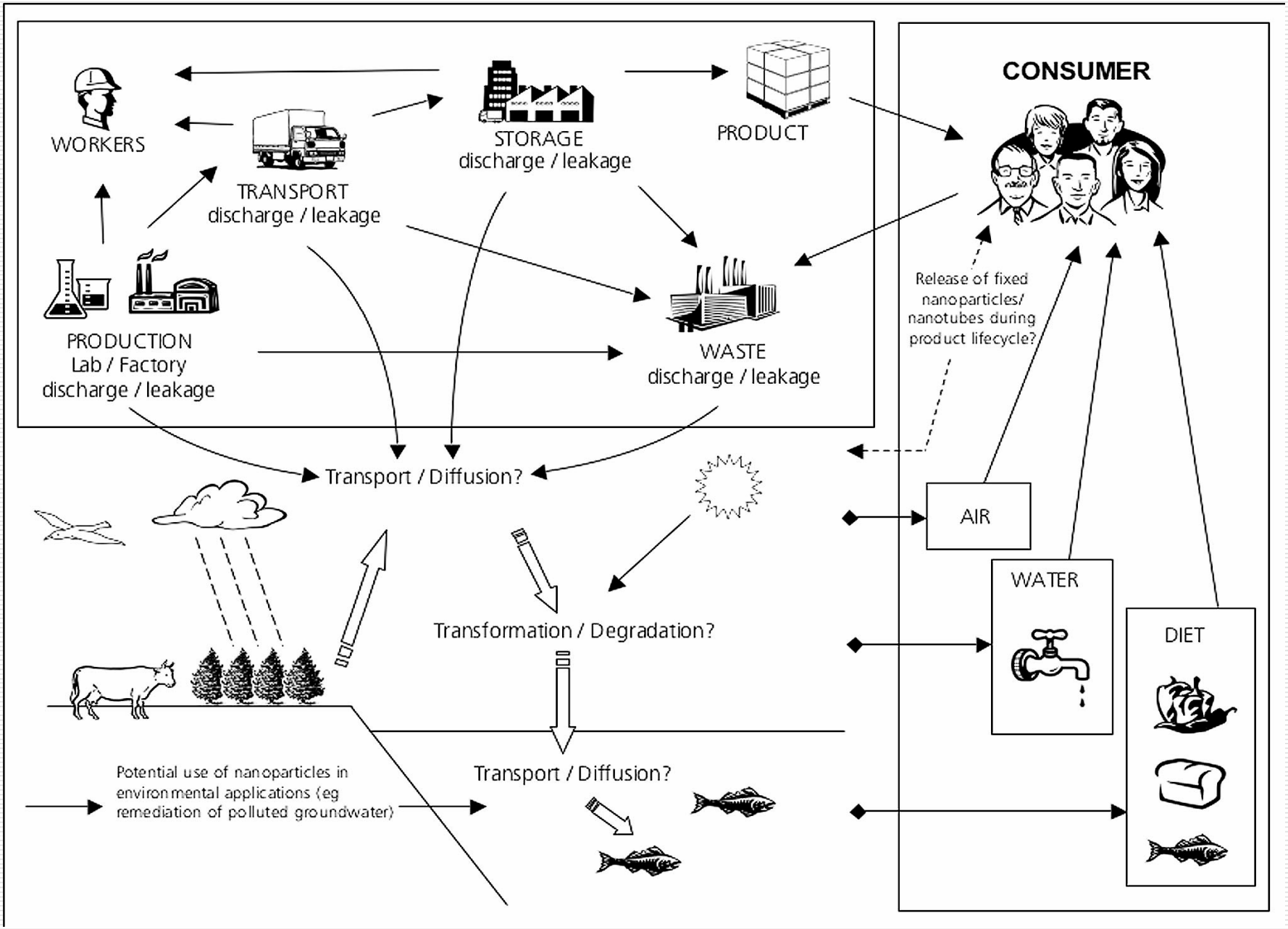
Nanoscale particles must have distinctly different properties than their larger counterparts -- otherwise, they wouldn't be so interesting to us…

Characterizing Hazard: Different Nanoparticle Types Merit Different Levels of Caution



Used with permission:. A Prudent Approach to Nanotech Environmental, Health and Safety Risks" Lux Research Inc 2005

Risk assessment Step 3: Exposure assessment



Royal Society Report July 2004

Matching hazard to applications

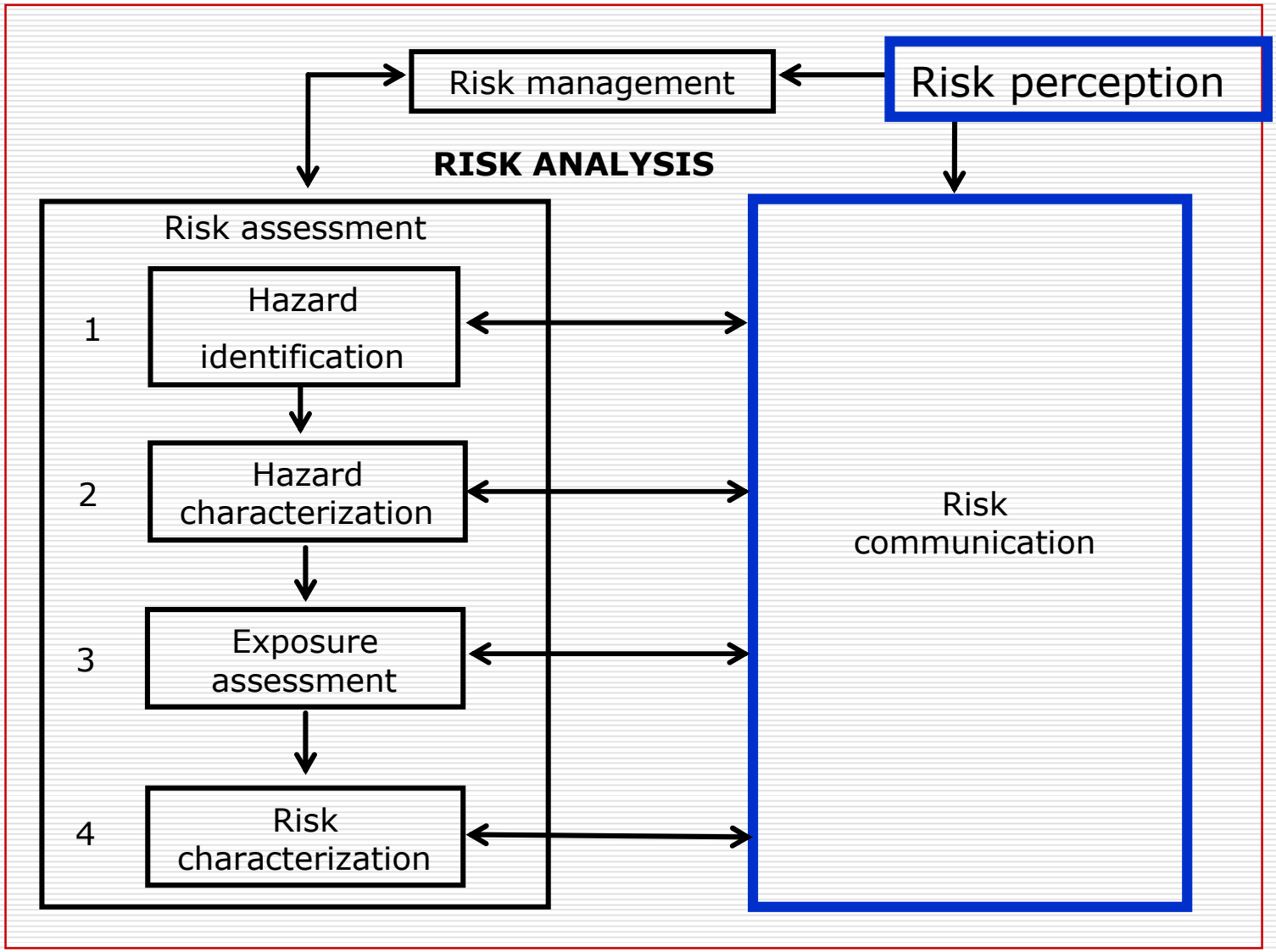
- Combining hazard characterization with exposure assessments
- Risk calculations
  - Susceptibility
  - Extrapolation models
    - (high-low)
    - (animal-human_
  - Value of mechanistic data from in vitro studies

Assessing and 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:

- Identifying Hazard
- 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 Perception: An additional component to the traditional risk analysis model



Risk: An Amended Perspective

- Quantitative

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

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

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

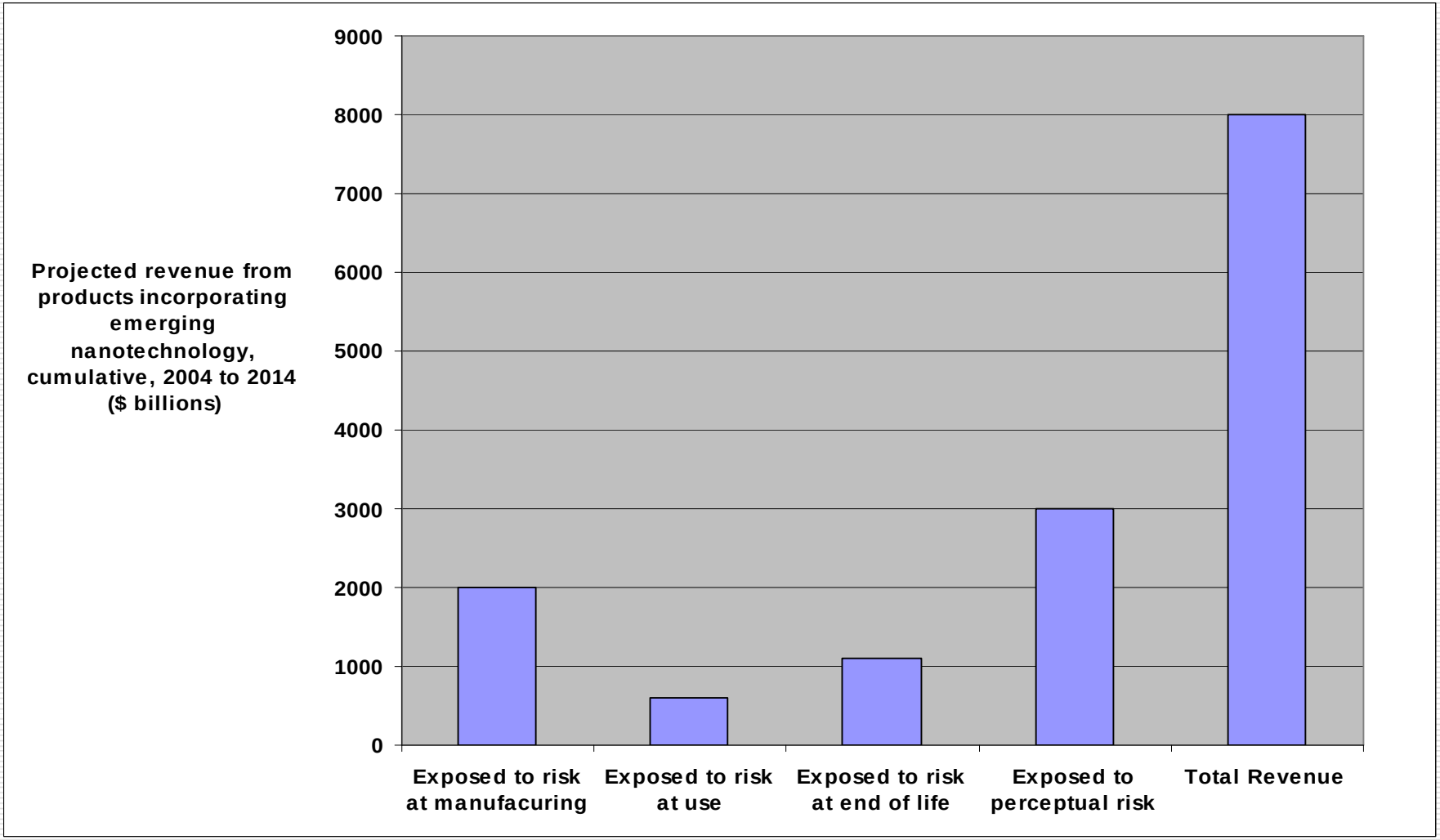
Sandman, P. Responding to Community Outrage: Strategies for Effective Risk Communication. AIHA 1993

Twelve Principal Outrage Components

"Safe"	"Risky"
1. Voluntary	☐ Involuntary
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

Sandman 1993

More Nanotechnology Revenue is Exposed to Perceptual Risk than Any Other Class



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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

What We Need to Know about Communicating Risk to the Public

- Normal people's response to risk is emotional and "rational" (cognitive) at the same time.
- You can't give people scary information without scaring them.
- People are usually able to tolerate anxiety and even fear, without escalating into terror or panic.
- Risk communication professionals have evolved techniques for helping people do so.
- Demanding that people stay unemotional about risk isn't one of the techniques that work.
- Demanding that the media suppress alarming content also isn't one of the techniques that work.
- Those who want to educate the public should first study how the public learns.
- All of the above generalizations are supported by data.

Explaining Environmental Risk: Dealing with the Public

- Risk perception is a lot more than morbidity or 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
- Explaining risk information is difficult but not impossible
- Risk communication is easier when emotions are viewed as legitimate
- Risk decisions are better when the public shares the power

Summary of Nanotechnology Risk Communication Challenges

- Public attitudes towards technological risks
- Public perceptions
- Media
- Trust

Recommendations

- Government needs to set clear and reasonable expectations for industry and ensure open involvement in the process
- Companies need to:
  - Involve EH&S professionals in emerging technology developments
  - Address benefits and both real and perceived risks when communicating on nanotechnology developments
- Increase the amount of allocation for nanoparticle toxicology research – need for tox screening tools
- Ensure engagement in open and ongoing discussions on nanotechnology EH&S risks

Summary

- Nanotechnology EH&S risks encompass not only that associated with health, safety and environmental impact of products, but also the public perception of the technology
- Perceived risk may play a greater role in technology development and public policy than identified risk
- There are effective means to communicate the new technology benefits and risks to the public
- The future of nanotechnology is bright so long as all parties are willing and able to discuss the EH&S risk issues openly.