Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Low Risks, High Public Concern?

The Cases of Persistant Organic Pollutants (POPs),

Heavy Metals, and Nanotech Particles

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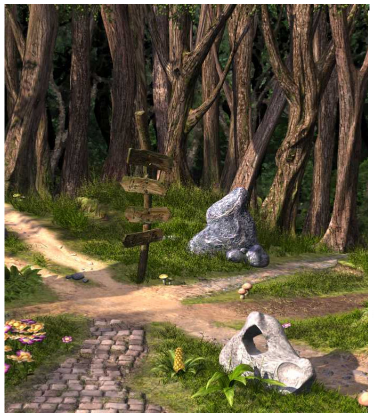
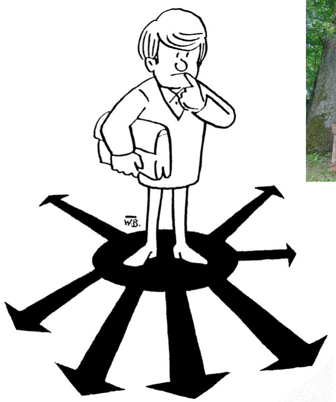
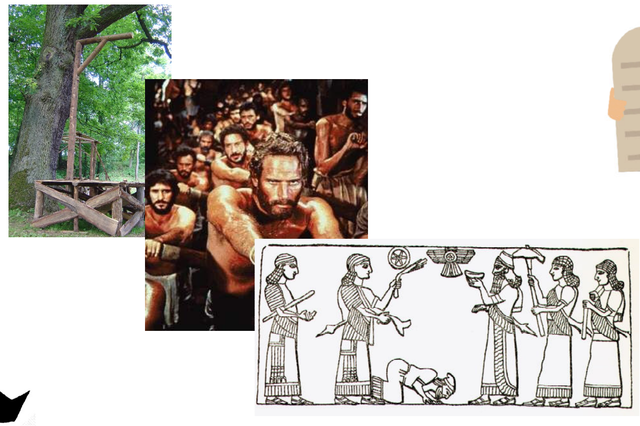
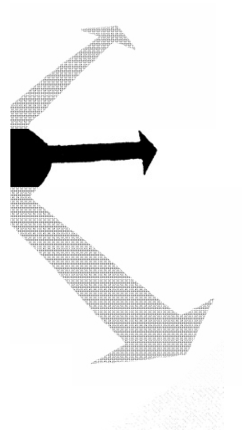
Where does the concept of risk come from?

- Mesopotamia, 3000 BC







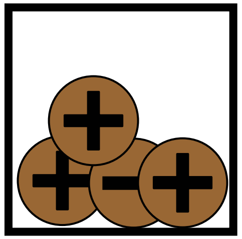


Decision Problem | Options for Action | Possible Future States | Risk Assessment | Decision

Where does the concept of risk come from?

- Mesopotamia, 3000 BC

  Ashipu were responsible for risk management



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Source: Arefaine, Saner & Blumer, 2007

Where does the concept of risk come from?
The risk management of Arnobius (about 440 AC)

	God exists	Goed does not exist
Believing in God	+	O
Not believing in God	–	O

Variants of Risks

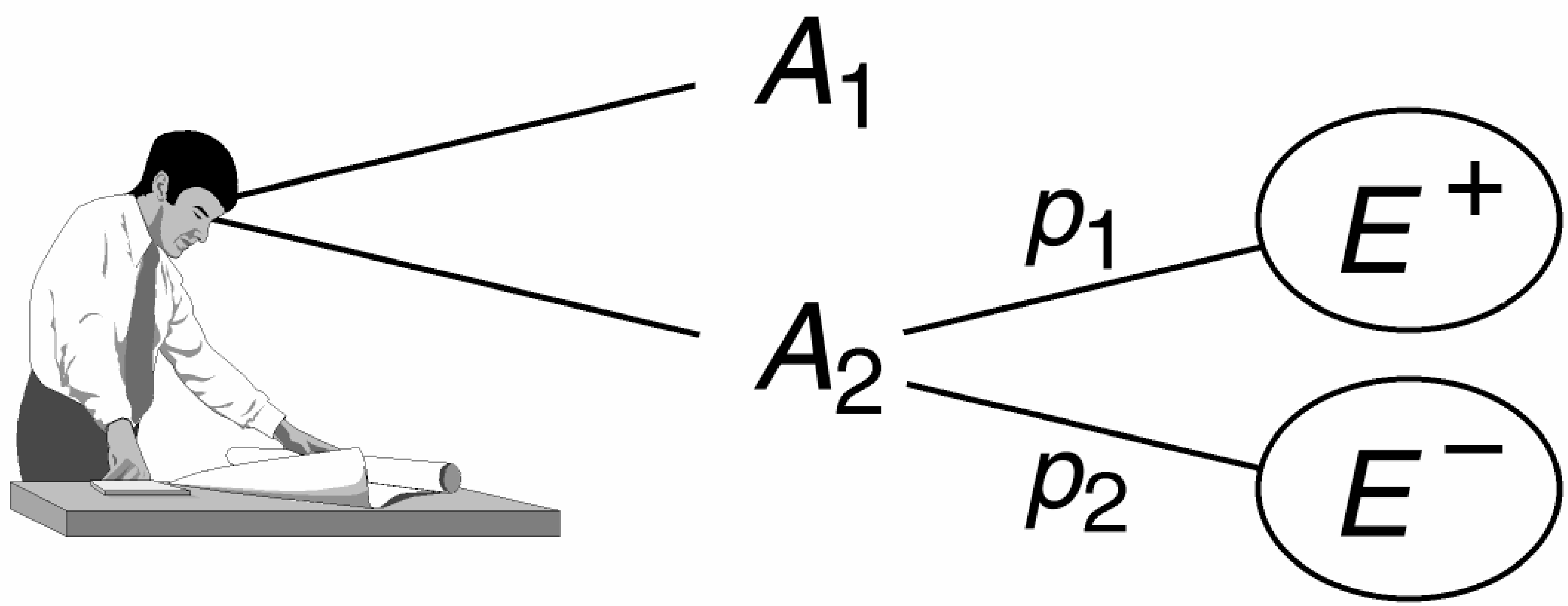
Formal Definition of Risk Situations

An Elementary Risk Situation is given by the following:

- There must be an agent having the choice between at least two alternatives A_1 and A_2.
- With the choice of one of the two alternatives, uncertainty arises: which event of two events E^+ or E^- will be the outcome of the chosen alternative.
- The agent considers the value, $v(E^-)$, of at least one uncertain event as a loss at least relative to the other event(s).

Variants of Risks

Formal Definition of Risk Situations



Variants of Risks

Formal Definition of Risk Situations

An General Risk Situation is defined as the following:

- An agent has the choice between different alternatives from a set $A = (A_1,\ldots,A_i,\ldots,A_n)$.
- For each alternative A_i, there is a set of possible events $E_i = (E_{i,1},\ldots, E_{i,n_i})$.
- For each alternative A_i, there is a probability vector $p_i = (p_{i,1},\ldots, p_{i,n_i})$. The probability $p_{i,j}$ denotes the probability of $E_{i,j}$ if A_i is chosen, $0 < p_{i,j} < 1$ for at least one i and j.

Risk ≠ Danger
Risk is different from danger

- When we talk about risk, we must have different strategies/alternatives we can choose and at least one negative outcome is linked to the alternatives
- Tsunami management (deciding where to allow settlements) is risk management
- The impaction of asteroids with a diameter of at least 1 km is a danger

Risk is "primitive", an elementary concept

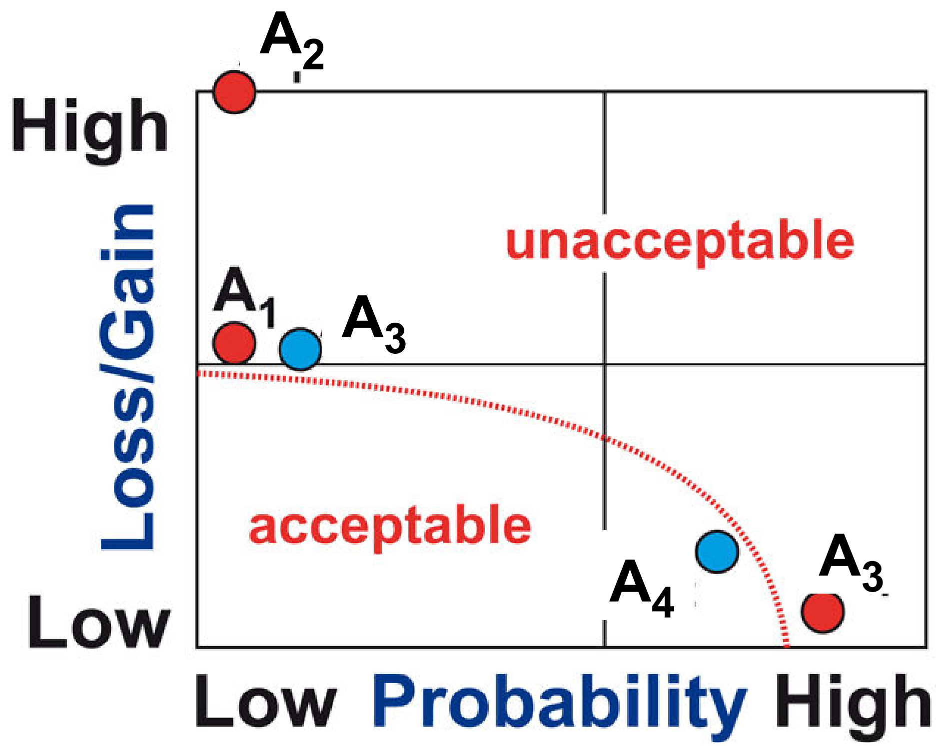
- (Almost) Everybody knows what is meant with risk
- It is an elementary concept in the sense of Kant
- Risk assessment and risk judgments provide evaluations

Variants of Risks

1. **Expected losses** (e.g. the expected number of people killed; insurances are/have been using this concept)
2. **Expected value** (the expected value of gains/losses; the banks are using this concept in the credit business)
3. **Largest Loss** (concerned people are using this concept)
4. **Combined evaluation of**
   - The **costs** of getting access to an alternative $A = (A_1,...,A_i,...,A_n)$
   - The **outcomes** that may result, if one alternative is chosen ($E(A_i) = (E_{i,1},...,E_{i,j},...,E_{i,j_i})$
   - The **probabilities** $p_{i,j}$ that certain events occur, if a certain alternative is chosen
5. For understanding differences in risk assessment and risk judgments it is important to distinguish between **pure riks** and **speculative risk**. Pure risk is only looking at the negative aspects. Speculative risk on positive and negative aspects.

Variants of Risks

Risk judgments are combining losses/gains and the probability of their occurence



Steps of Risk Assessment (in toxicology; e.g. for heavy metals, POPs, nanotech particles)

1. Defining the risk situation
2. Defining the negative effects
3. Assessing the dose-response relationship
4. Assessing the exposure
5. Characterizing the risk

Risk Assessment Methods

The risk (e.g. the expected health effects, DALYS) can be assessed by

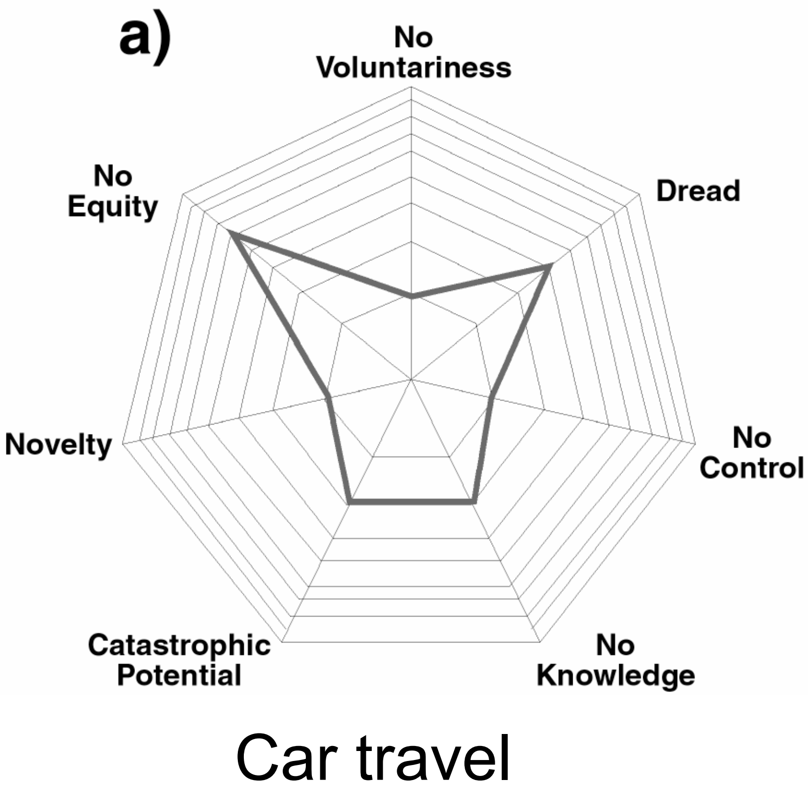
- Epidemiological Studies
- Animal Experiments
- Low-dose Human Experiments
- Expert Judgments for Cases
- (Simulation)
- ...

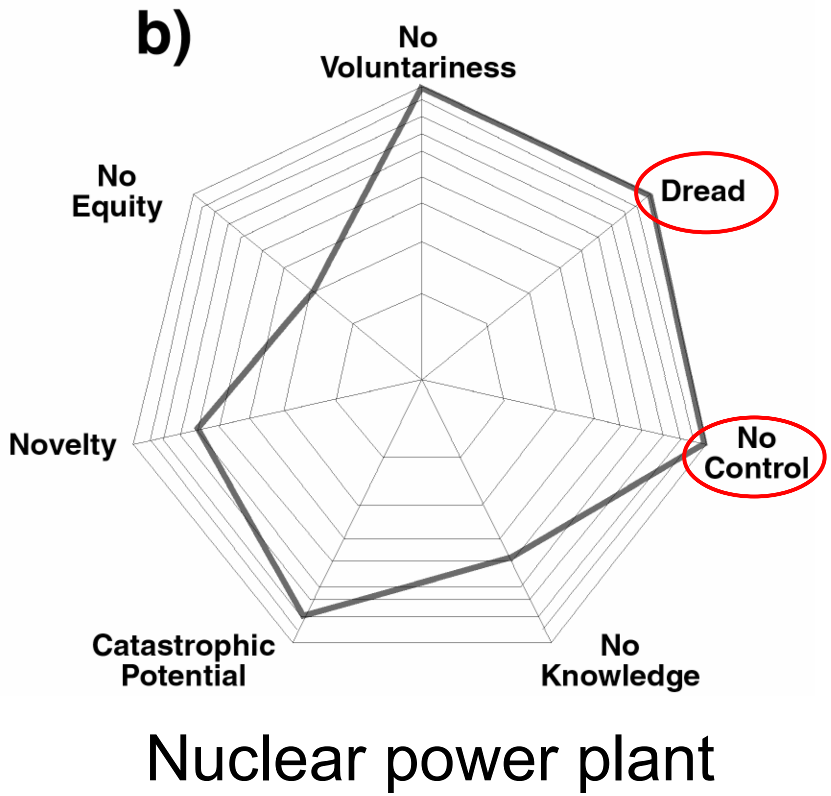
Risk assessment ≠ risk perception

- Risk assessment is a science based procedure and evaluation. It is provided by (groups) of scientists
- Risk perception is based on a psychological process. It is provided by an individual (or ba a group).

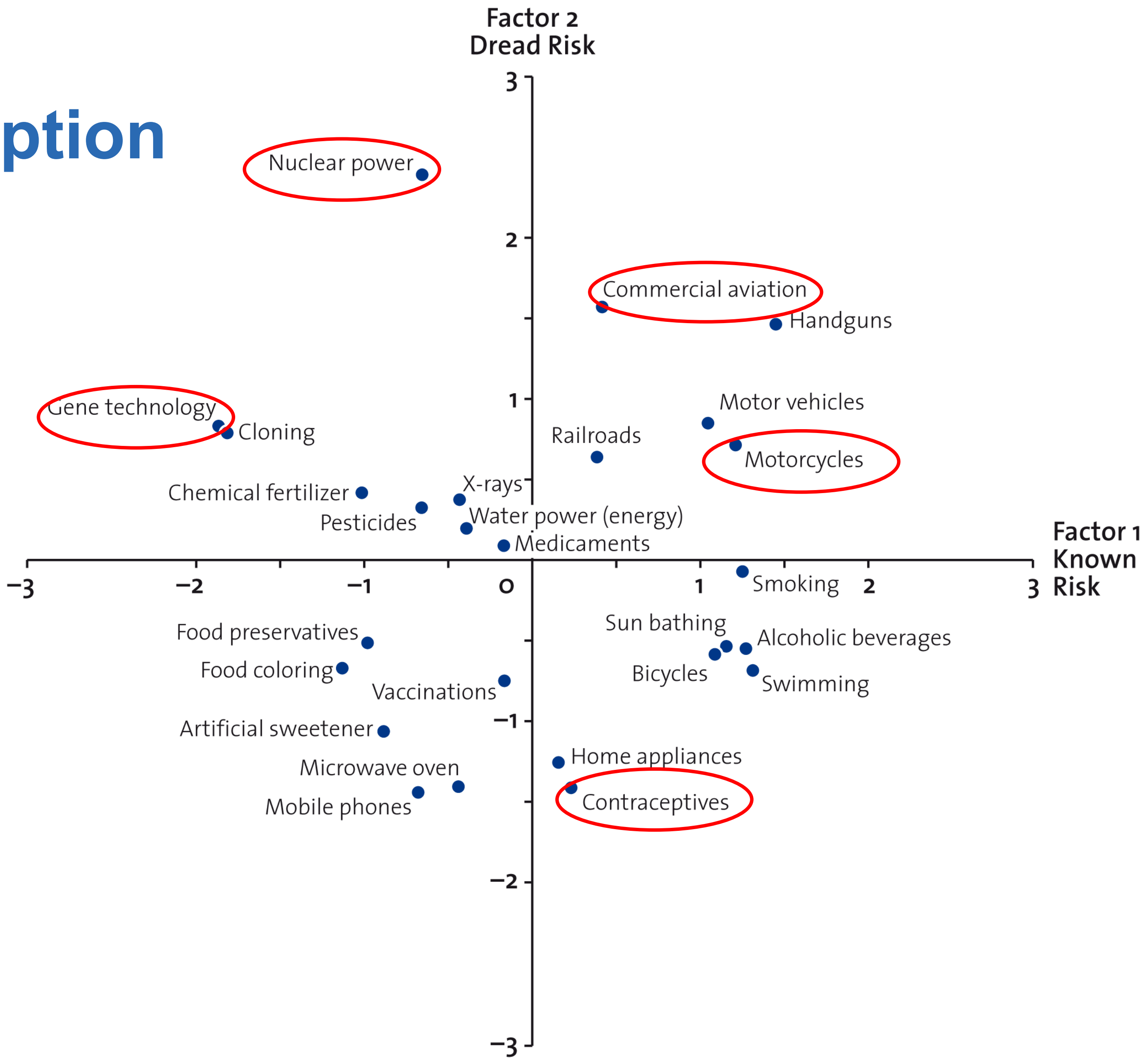
Risk Perception:
What's happening in the mind of people

Psychological, risks (risk situation) have a „personality", i.e. can be characterized by different aspects (Slovic et al. 1979)





Risk Perception



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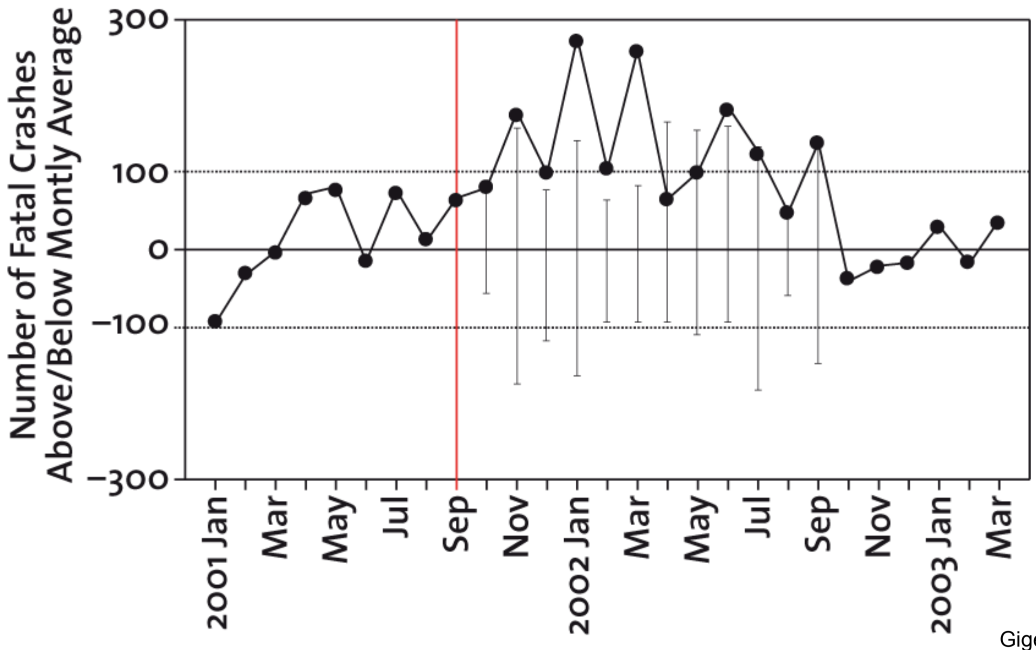


Gigerenzer 2006

The cases:
Heavy metals

The Cases – Heavy Metals

What are Heavy Metals?

- "Heavy metals" are chemical elements with a specific gravity that is at least 5 times the specific gravity of water.
- Antimony, **Arsenic**, Bismuth, **Cadmium**, Cerium, Chromium, Cobalt, Copper, Gallium, Gold, Iron, **Lead**, Manganese, **Mercury**, Nickel, Platinum, Silver, Tellurium, Thallium, Tin, **Uranium**, Vanadium, and Zinc

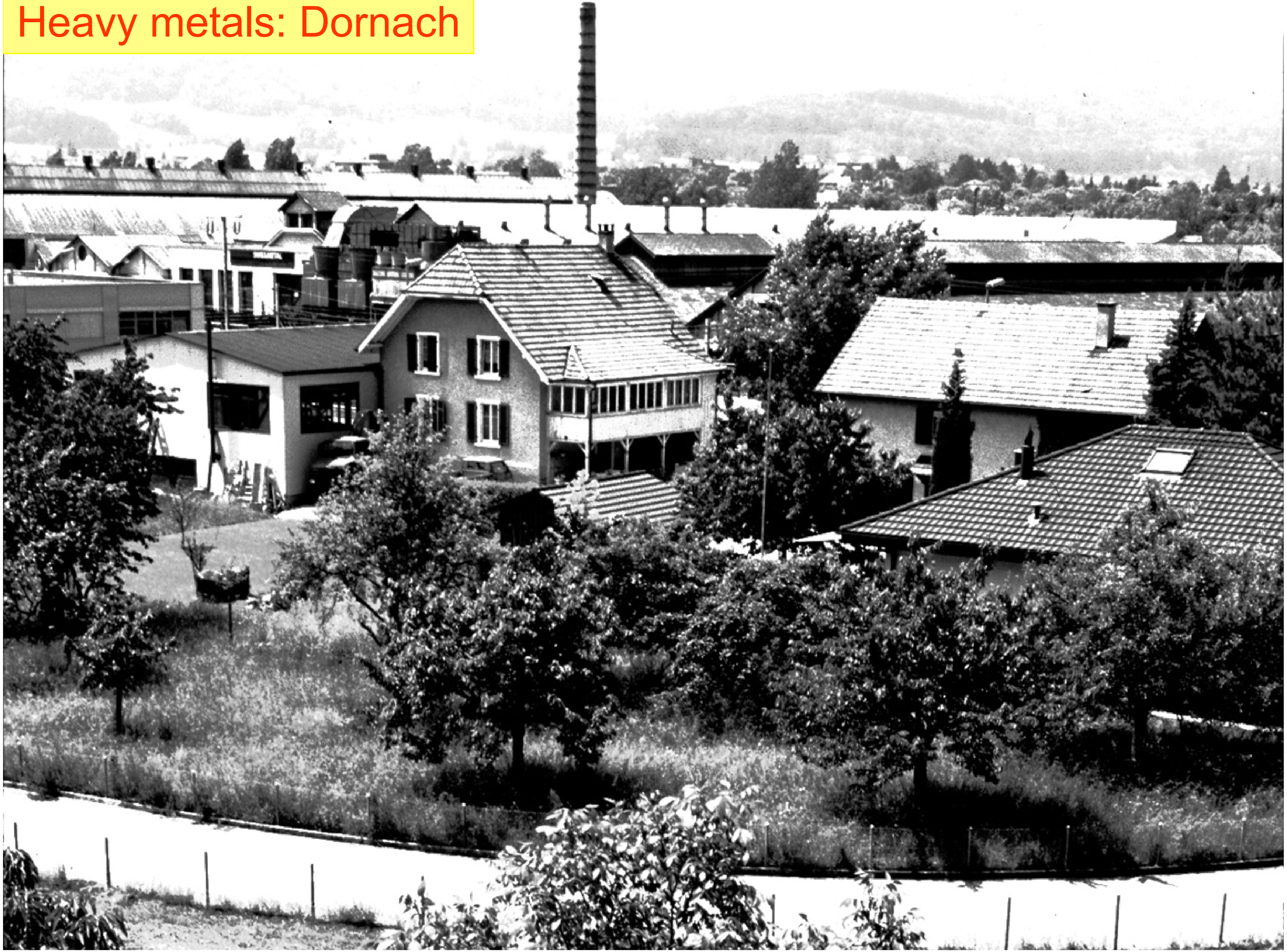
U.S. Department of Labor http://www.osha.gov/SLTC/metalsheavy/index.html

The Cases – Heavy Metals

Where do they come from?

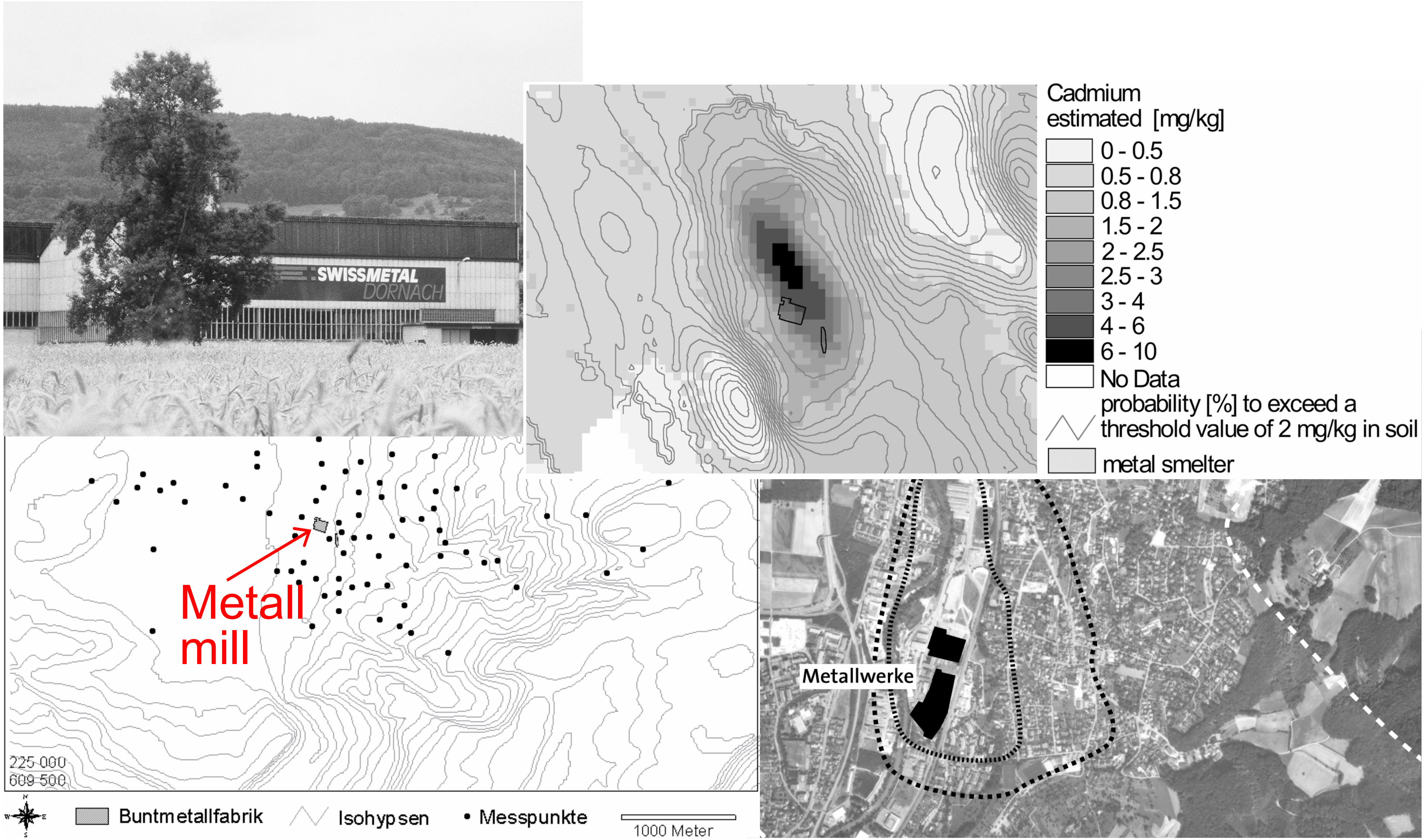
- Geogene background layer
- Mining
- Industrial production (metal production, smelting, galvanic industry, etc)
- Combustion processes
- Waste, waste water
- Agricultural products
- Smoking
- ...

Heavy metals: Dornach



Heavy metals

The situation in Dornach: “Large scale” contamination with Cadmium, Copper, and Zinc



The Cases – Heavy Metals

Where do we find them in the environment?

In all environmental compartments and species!

- Heavy metals are natural components of the Earth's crust.
- Heavy metals can enter a water supply by industrial and consumer waste, or even from acid rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater.

Source: http://www.lenntech.com/heavy-metals.htm

The Cases – Heavy Metals

What negative effects do they have?

- Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues (copper, selenium, zink etc. are essential elements to maintain metabolic processes).
- Possible symptons of toxication are:
  - Cramping, nausea, and vomiting
  - Pain
  - Sweating
  - Headaches
  - Difficulty breathing
  - Impaired cognitive, motor, and language skills
  - Mania
  - Convulsions
  - …

The Cases – Heavy Metals

Risk assessment of some Heavy Metals; Swiss threshold values; note the bioavilable part provides other data

Category of utilization	Total concentration (mg/kg dried matter for soil up to 15 % Humus, mg/dm^3 for soil over 15 % humus)				Sampling Depth (in cm)
	Lead (Pb)	Cadmium (Cd)	Copper (Cu)	Zinc (Zn)	
Agri- and Horticulture	2'000	30	1'000	2'000	0Š20
Garden and Allotment	1'000	20	1'000	2'000	0Š20
Play-grounds	1'000	20	Š	Š	0Š5

Source: Swiss Federal Council, 1998

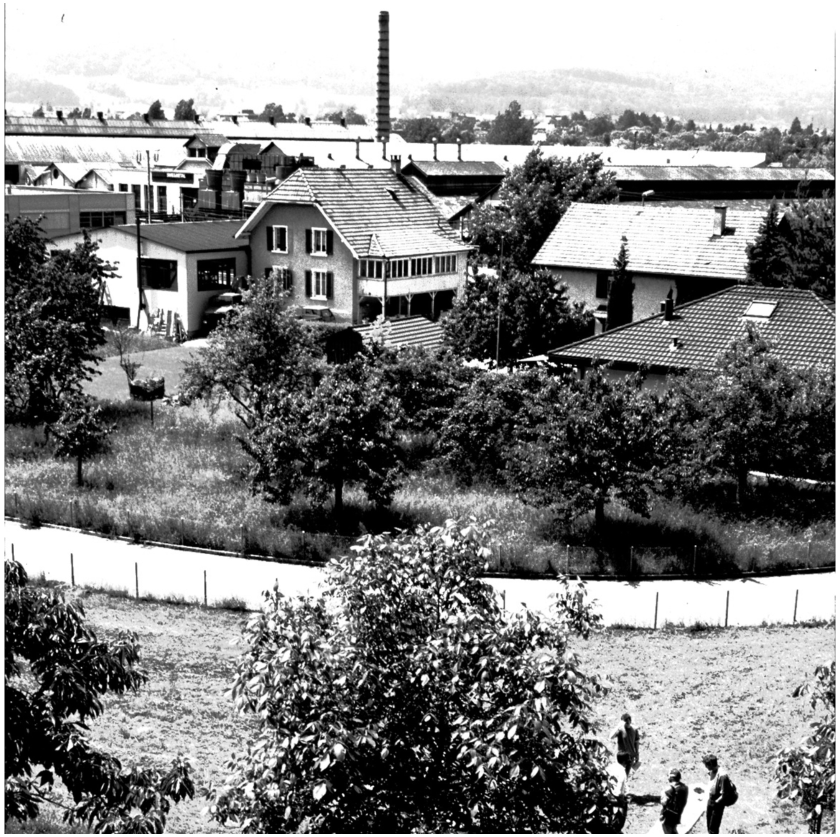
The Cases – Heavy Metals

Conclusions on the assessment

- The risk of most metals are well assessed
- No real disputes about toxicity (Paracelsus principle still dominating)
- The exposure to and the impact of interaction among different metals are not well known
- High tech technological industrial production can easily reduce the emission of heavy metals

The Cases – Heavy Metals

Risk Perception



Critical questions investigated:

- Is the risk of heavy metals appropriately perceived?
- What characteristics are linked with heavy metals?
- How does the judgment of people concerned differ from the judgment non-concerned people?
- When do people become very sensitive?

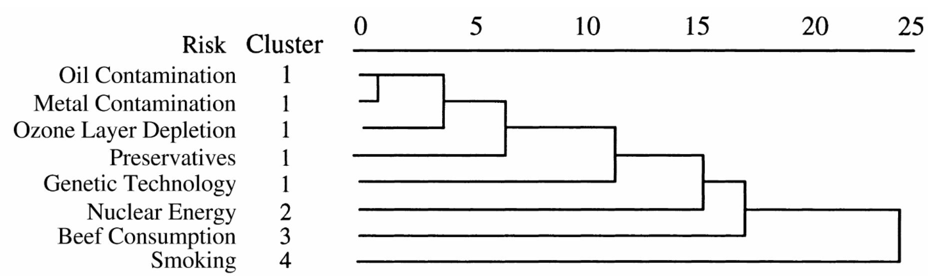
The Cases – Heavy Metals

Risk Perception

Critical questions investigated:

- Is the risk of heavy metals appropriately perceived?
- What characteristics are linked with heavy metals?
- How does the judgment of people concerned differ from the judgment non-concerned people?
- When do people become very sensitive?

- Similar to oil, ozone layer, and preservetives
- Medium with respect to controllability
- No (or indifferent) to dread
- No catastrophic potential



The Cases – Heavy Metals

Risk Perception

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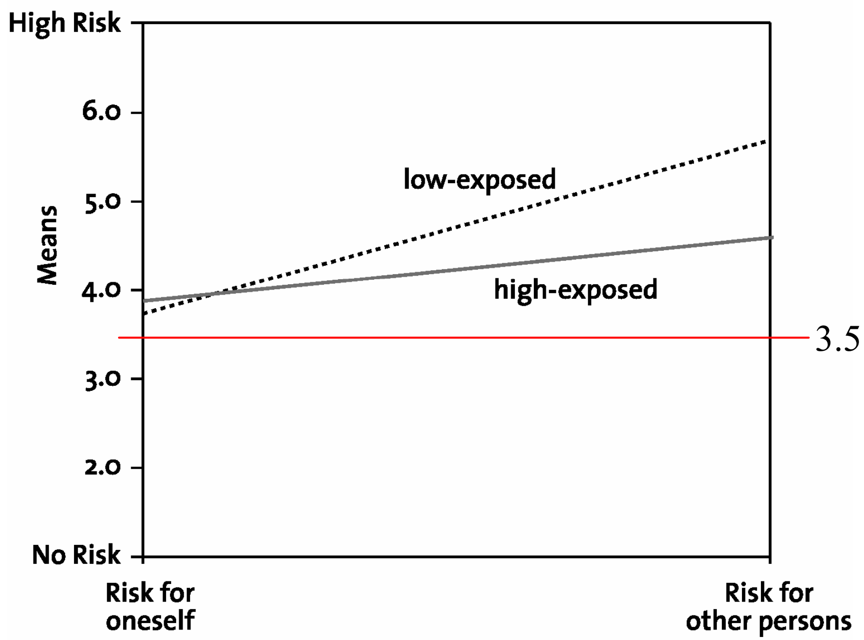


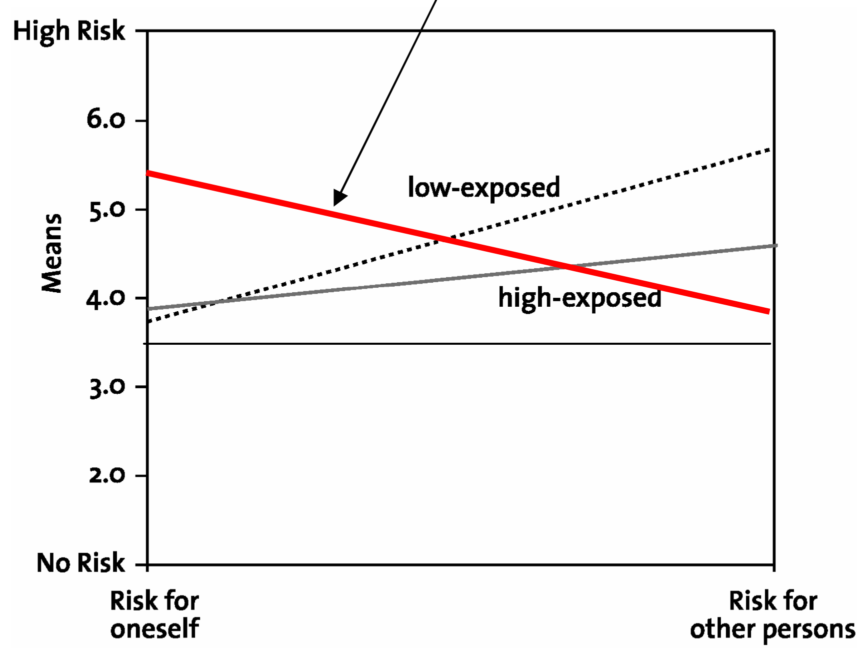
The Cases – Heavy Metals

Risk Perception

Critical questions investigated:

- Is the risk of heavy metals appropriately perceived?
- What characteristics are linked with heavy metals?
- How does the judgment of people concerned differ from the judgment non-concerned people?
- When do people become very sensitive?

This should be the rating of the exposed group



- The illusion of control seems to be at work at exposed people!

The Cases – Heavy Metals

Conclusions

- The toxicity of heavy metals is well explored (classical risk assessment works)
- Exposure results from multiple sources (food, air, smoking, water, ...)
- The dose-respose curves are well known
- There's a worldwide consensus that severe environmental standards are beneficial in a multiple way (from health costs to industrial competivenes)
- People (in Central Europe) are reasonable judging the risk of heavy metals
- There are interesting "paradoxes" of judging oneself and others

The case
Persistant organic pollutants

The Cases – POPs Persistant Organic Pollutants

What are POPs?

- POPs are chemicals thqt resist degradation (critical times are 2 months in water, 5 months in soil; bioaccumation about 5000)
- There are 100,000 registered chemicals; 30,000 to 70,000 in daily use
- Well-known examples are chlorine compounds (e.g. DDT, PCDDs, PCDFs, lindane, dieldrin, endrin, PCB)
- Also carcinogenic polycyclic aromatic hydrocarbons (PAHs, Benz-a-pyrene) are considered POPs
- Description see Stockholm Covention on POPs, signed by 150 counties on 17 May 2004, http://www.pops.int/

The Cases – POPs Persistant Organic Compounds

Where do they come from?

- POPs are caused by many human activities including chemical industry (color, chlorine production) combustion for energy production and transportation, industrial processes, and agricultural uses of pesticides
- Historically, organoclorine insecticides (biocides) and the food chain were the primary sources of human uptake

The Cases – POPs Persistant Organic Compounds

Where do we find them?

- 300 million tons of synthetic compounds are used each year
- 140 million tons fertilizers
- 5 million tons pesticides

- POPs can be found in all environmental compartments and are accumulated particularly in fat tissues
  - Long travel distances in water
  - Many are semi-volitily, long-distance transport in air

The Cases – POPs Persistant Organic Compounds

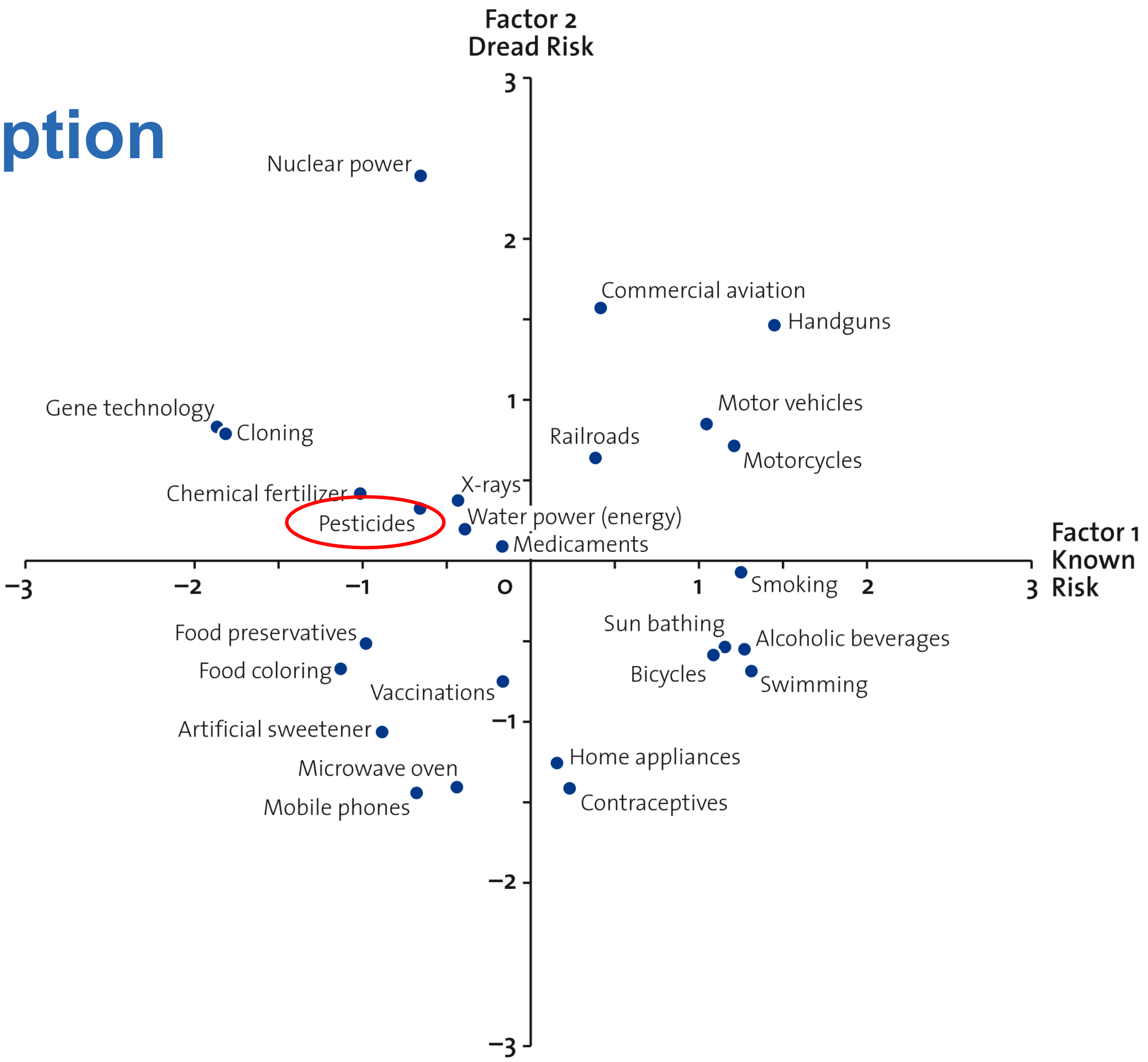
What negative effects do they have?

- POPs have negative effects primarily in aquatic, soil, and organismic systems
- The are bioaccumulated in *fat tissues* (animal fat)
- WHO estimates that 3 million farmers experience severe poisoning by pesticides, about 18,000 die each year
- POPs cause multiple effects in human and animals including
  - Cancer
  - Neurologic diseases
  - Immune system disorders,
  - Birth effects, infertility

POPs Persistant Organic Compounds
Risk assessment of some POPs

- Human risks: 90% of uptake of the (known) 15 to 50 critical chemicals occur by diet (fish, meat, ...)
- Human risk assessment comes to its limits
  - High number of chemicals
  - Their interaction
  - Metabolic processes
  - Their “efficiency”, they harm by very low concentration
- Environmental risks
  - POPs are a major threat of water quality
  - Ecosystems: The mutual interaction of thousands of chemicals in the environment with millions of biological species will ultimately determine whether a given pollutant (mixture) leads to marginal or catastrophic ecological consequences. (Schwarzenbach et al., 2006, Science p. 1075)

Risk Perception



Conclusions on POPs

- We are starting to get a good knowledge about dangerous POPs (see Stockholm convention)
- Classical risk assessment comes to its limits in ecosystem health (but also in human health; the OECD concept of systemic risk seems appropriate)
- There is evidence of illusionary control of concerned people (sport fisherman ignore the increased risk)
- Trust, dread, and the stigmatization matter
  - The example of municipal waste incineration in Switzerland and the U.S.
    - In Switzerland 99% of all municipal waste (which can nor be efficiently recycled such as paper, metal, glass, batteries) is burned
    - There is an old incinerator Josephstrasse in operation since 1904. Now a fancy upper middle-class Loft-living area with 10'000 residents is booming just in the neigbourhood (distance less than 100 meters) has been build (The living quality in the City of Zurich is worldwide ranked between 1 and 3).

Missing trust in incinerator companies and fear of dioxine and toxic ash is preventing incinerators in GB and the U.S.

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The case
Nanotech particles

Nanotechnology

- A nanometre (nm) is one thousand millionth of a metre (i.e. 10^{-12} m; the **length of 4 neighboured metal atoms**)
- People are interested in the nanoscale (0.2 - 100 nm) because it is at this scale that the properties of materials can be very different from those at a larger scale, engineering on the scale of atoms
- Properties of materials can be different at the nanoscale
  - Relatively **larger surface**
  - Quantum effects can begin to dominate the behavior of matter

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The Case Nanototech Particles

What are Nanototech Particles?

- Nanoparticles (nanopowders, nanoclusters, nanocrystals) are particles with at least one dimension less than 100 nm.
- Nanostructures can be divided in
  - Nanofilms
  - Nanowires
  - Nanotubes
  - Nanoparticles
- Typical examples are
  - Nano-titanium, -taniumdioxide, -alumina, -zinc, -silver, carbon black, and carbon nanotubes

The Case Nanototech Particles

Where do they come from?

Nanoparticles derivation can be divided into:

I. Nonengineered, combustion-derived nanoparticles (like diesel soot),

II. Manufactured (engineered) nanoparticles like carbon nanotubes

III. Nonengineered, naturally occurring nanoparticles from volcanic eruptions, atmospheric chemistry etc.

Current applications of engineered

Nanoparticles

Engineered nanoparticles are intentionally designed and created with physical or chemical properties to meet the needs of specific applications.

Figure:
Carbon black, commonly used to enhance the properties of manufactured rubber, is clearly visualized using the NANO-R™.

http://www.pacificnano.com/nanoparticles_applications-for-nanoparticles.html

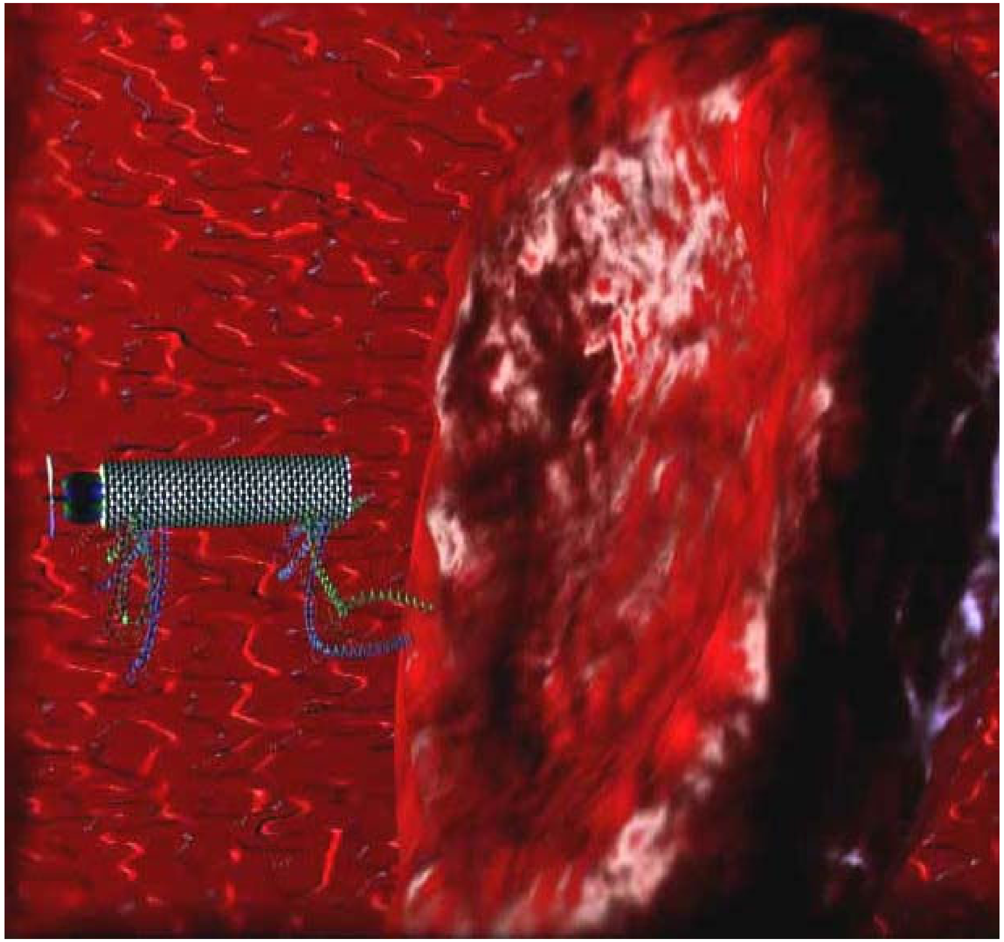
Current applications of nanoparticles (cont.)

Properties	Applications/potential emission sources to the environment
Electronic	High performance and smaller components, e.g, capacitors for small consumer devices such as mobile phones; displays that are cheaper, larger, brighter, and more efficient; high conductivity materials
Optical	Anti-reflection coatings; tailored refractive index of surfaces; Light based sensors for cancer diagnosis
Magnetic	Increased density storage media; nano-magnetic particles to create improved detail and contrast in MRI images
Thermal	Enhance heat transfer from solar collectors to storage tanks; Improve efficiency of coolants in transformers
Mechanical	Improved wear resistance; new anti-corrosion properties; New structural materials, composites, stronger and lighter

Current applications of nanoparticles (cont.)

Properties	Applications/potential emission sources to the environment
Energy	High energy density and more durable batteries; hydrogen storage applications using metal nano-clusters; Electrocatalysts for high efficiency fuel cells; Renewable energy, ultra high performance solar cells; Catalysts for combustion engines to improve efficiency, hence economy
Biomedical	Antibacterial silver coatings on wound dressings; sensors for disease detection (quantum dots); programmed release drug delivery systems; “interactive” food and beverages that change color, flavor or nutrients depending on a diner’s taste or health
Environmental	Clean up of soil contamination and pollution, e.g. oil; Biodegradable polymers; Aids for germination; treatment of industrial emissions; more efficient and effective water filtration
Surfaces	Dissolution rates of materials are highly size dependant; activity of catalysts, coatings for self cleaning surfaces, Pilkington’s glass for example.
Personal care	Effective clear inorganic sunscreens

http://www.malvern.com/LabEng/industry/nanotechnology/nanoparticle_applications.htm



Scientists at Rutgers University believe that nano-sized robots will be injected into the bloodstream in 2020, and administer a drug directly to an infected cell.

This robot has a carbon nanotube body, a bio-molecular motor that propels it and peptide limbs to orient itself.

Because it is composed of biological elements such as DNA and proteins, it will be easily removed from the body.

(http://bionano.rutgers.edu/Mavroidis_Final_Report.pdf)

The Cases – Nanototech Particles

Where do we find them in the environment?

- Combustion-derived nanoparticles
  - Urban exposure
  - Exposure to nanoparticles derives mostly from traffic, e.g. diesel soot, which is well-known to produce a range of adverse human health effects.
- Engineered nanoparticles
  - Occupational exposure
  - In the search for novel nanoparticles a whole new range of different nanoparticle types are being produced in small quantities for experimental purposes or in bulk.

The Cases – Nanotech Particles (cont.)

Where do we find them in the environment?

- Engineered nano-particles (cont.)
  - Manufacture exposure
  - The release of nano-particles in industrial effluent could lead to contamination of ecosystems. Eventually, as nano-particles are mass-produced and introduced into more products, there will inevitably be a risk of release of nano-particles into the environment.

Nano-tech Particles

What negative effects do they have?

The potential health risk from engineered nanoparticles is largely unknown:

- Exposure to extremely fine particles, has been associated with increased morbidity and mortality from lung and cardiovascular disease.
- Exposure from traffic, e.g. diesel soot is well-known to produce a range of adverse human health effects.These seems to occur in well-defined, already-ill populations, that include asthmatics and those with smokers lung disease – COPD (Chronic Obstructive Pulmonary Disease). However, the biggest adverse health impact seems to be in people with cardiovascular (heart and circulatory) disease who suffer from increased hospitalisations and deaths.

Nanototech Particles

What negative effects do they have? (cont.)

- Interactions between nanoparticles and the skin is a special case since nanoparticles are already present in e.g. sunblock cream. There is little known about the transfer of nano-particles across the skin or their ability to harm skin and so much more research is needed in this area
- Nano-particles are also present in processed food, but it isn't known whether they produce adverse effects e.g.on the gut
- All of these findings are new and so although we do understand in part the action of these types of environmental nano-particles, but we are far from having a complete picture

The Cases – Nanototech Particles

Risk assessment of Nanotech Particles

The traditional risk assessment methodology which consists of

1. Defining the risk situation
2. Hazard identification
3. Dose-response relationship identification
4. Exposure assessment
5. Risk characterization

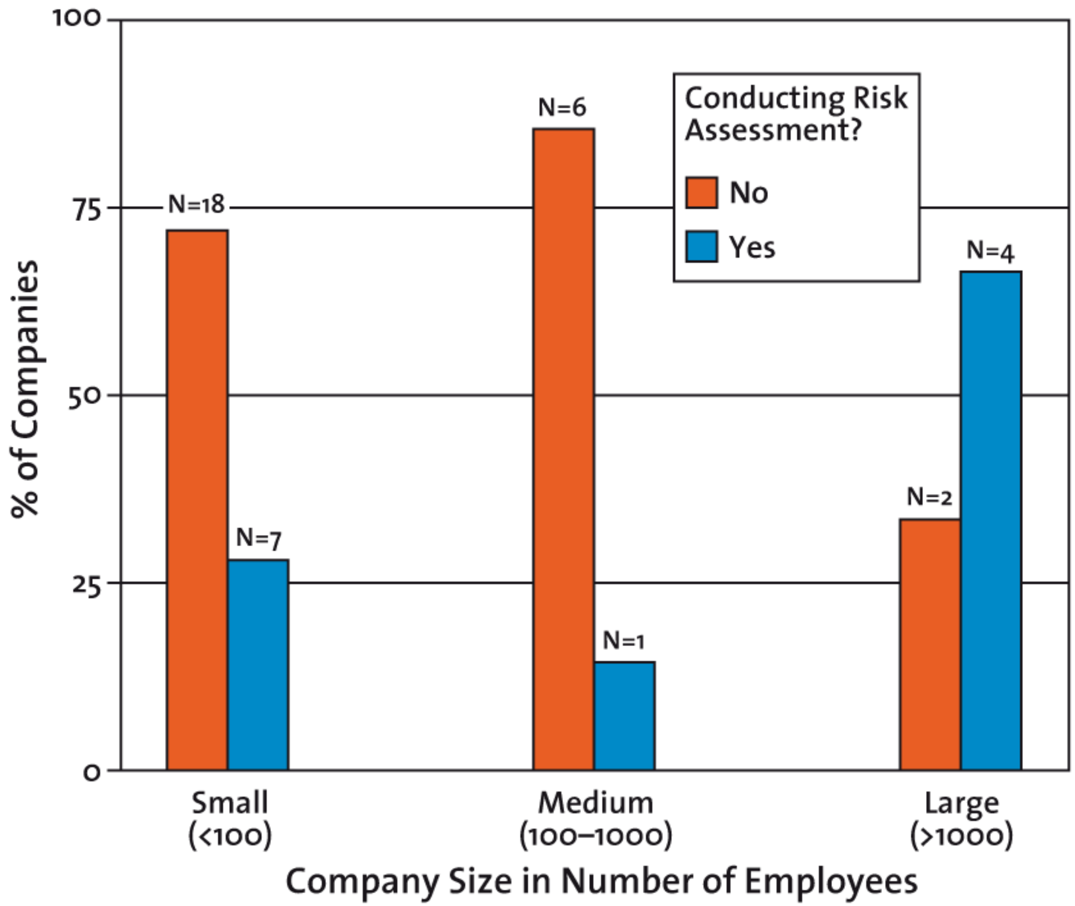
has not yet been applied (at least not quantitatively) to nano-particles.

The Cases – Nanototech Particles

Risk assessment of Nanotech Particles (cont.)

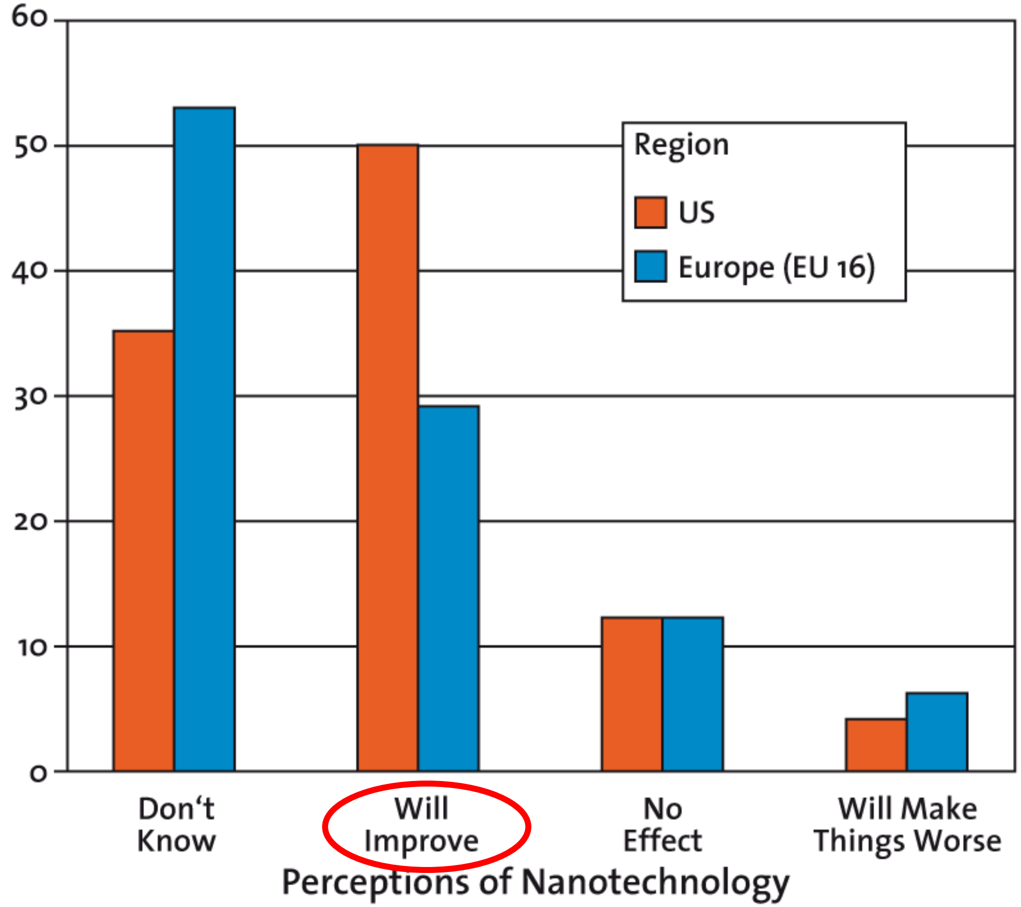
- Asbestos like impacts on the lung
- Engineered chemicals in their nano-particle form may have properties that are completely different from their larger physical forms and may therefore interact differently with environmental systems
- No developed guidelines exist on testing procedures. Current risk assessment methodologies may not be adequate for the case of nano-particles
- Risk **assessment** research programs started in many places of the world.

Risk Assessments are not voluntarily done by companies



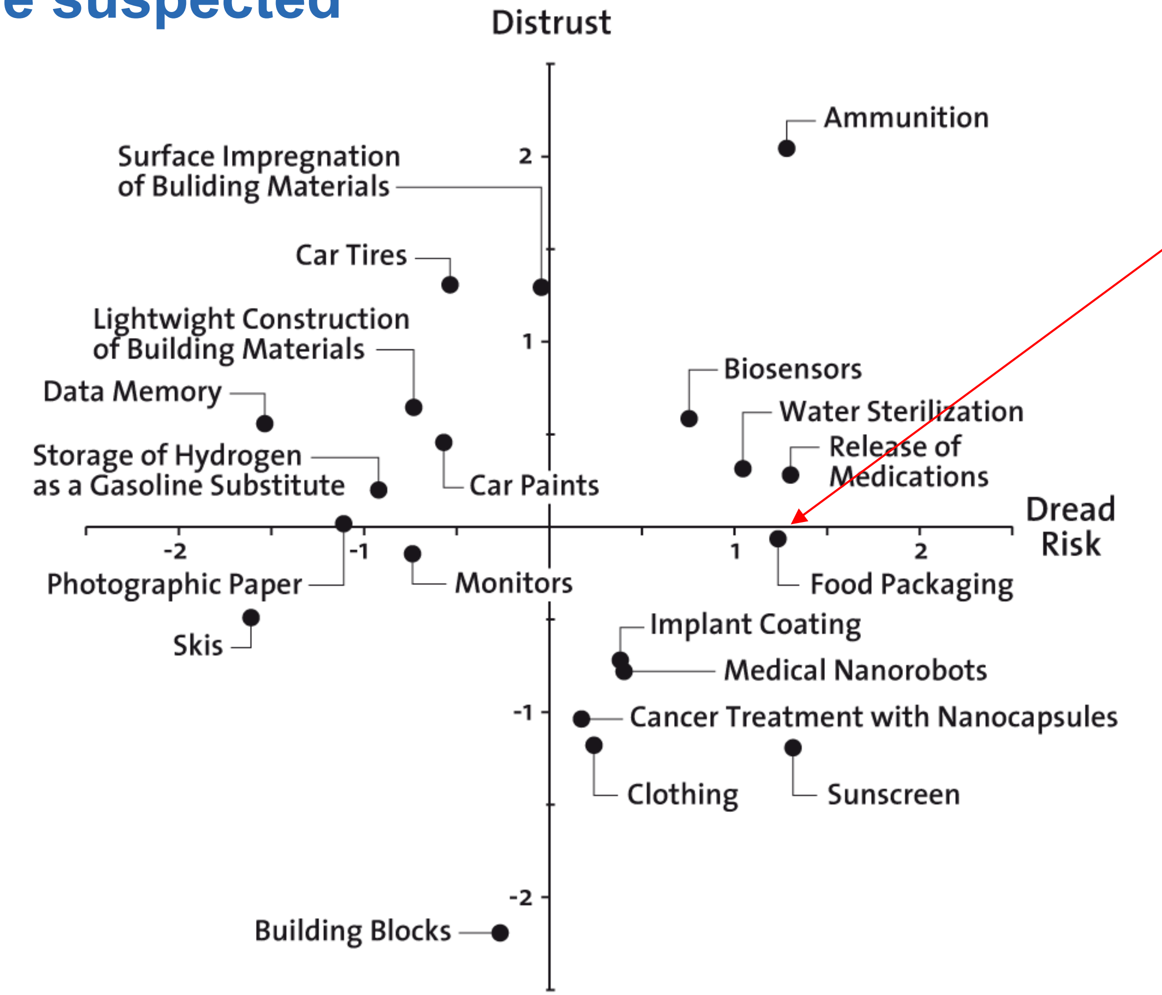
- 135 companies have been asked to respond
- 40 answered
- 12 made “some” voluntary risk assesment
- 26 made no voluntary risk assessment

Survey Results: People are gentle to nanotech because the expect positive effects



Gaskell et al., 2005

Psychometric Paradigm. What applications of nanoparticles are suspected



Summary with respect to Nanotech Particles

- Engineered nanotech particles may induce new, unknown health and environmental risks
- Besides plausible (asbestos like) lung damages not much is known
- Only few companies perform a volunteer risk assessment
- Perceived dreadfulness of applications and trust in governmental agencies are important factors in risk perception
- (US and European) Laypersons perceive greater risks than experts
- People get sensitive with food-products

Four general conclusions on low risk and high public concern?

1. Risk assessment: We have different knowledge about different risk

- Heavy metals and POPs are considerable real risks with severe impacts on human and ecosystem health; nanotech particles might have the potential
- From a natural science perspective we have classical, measurable dose-response relationships (e.g. for heavy metals such as Cadmium) and systemic risks which consist of subtle changes of the whole system (such as POPs impacts in aquatic systems)

2. There are different concepts of risk

- There are different concepts of risk! (Risk is a construct!) The difference between
  - **pure risk** (just looking at the negative issues) and **speculative risk** (looking at the distribution of positive and negative results) may explain different risk judgments and thus th dissent among parties
  - Pure risk as the **expected number of deaths** and the pure risk as **the highest number of possible deaths** can explain differences among people concerned and people from an environmental protection agency
- These different concepts can be at work both in risk assessment and risk perception

3. Emotional concern, symbolic values etc. can lead to oversensitive risk perception of the public

- Stakeholder views (economists vs. environmentalists) are at least as important as cultures
- People are aware of risks heavy metals, POPs, nanotech particles, but none of these are (currently) **stigmatized** such as GMOs or nuclear waste
- People's intuitive risk judgments depend on
  - The "symbolic value" of the safeguard objects (see Rachel Carson's successful campaign against DDT when she proposed the effect on birds [e.g. the American eagle]) or the perceived importance of safeguard objects [e.g. babies]
  - For risk judgments, emotional concern is more important than objective concern
  - Emotional concern and trust (into the public authorities, companies etc.) are most important in risk judgments

4. Risk assessment and risk perception are related

- Science “news” affect the public (media). And what is considered being an important safeguard at risk is determined by the public
- If the public looses trust and lacks control, risk perception can become a real problem
- Good risk assessments, good and open risk information are key issues of successful and sustainable risk management!