A qualitative approach to risk assessment and control in engineered nanoparticles occupational exposure

Francisco Silva[a,b], Pedro Arezes[b], Paul Swuste[c]

a: Technological Centre for Ceramic and Glass
b: Human Engineering Group, Production and Systems Department, University of Minho
c: Safety Science Group, Delft University of Technology

E2N 2103

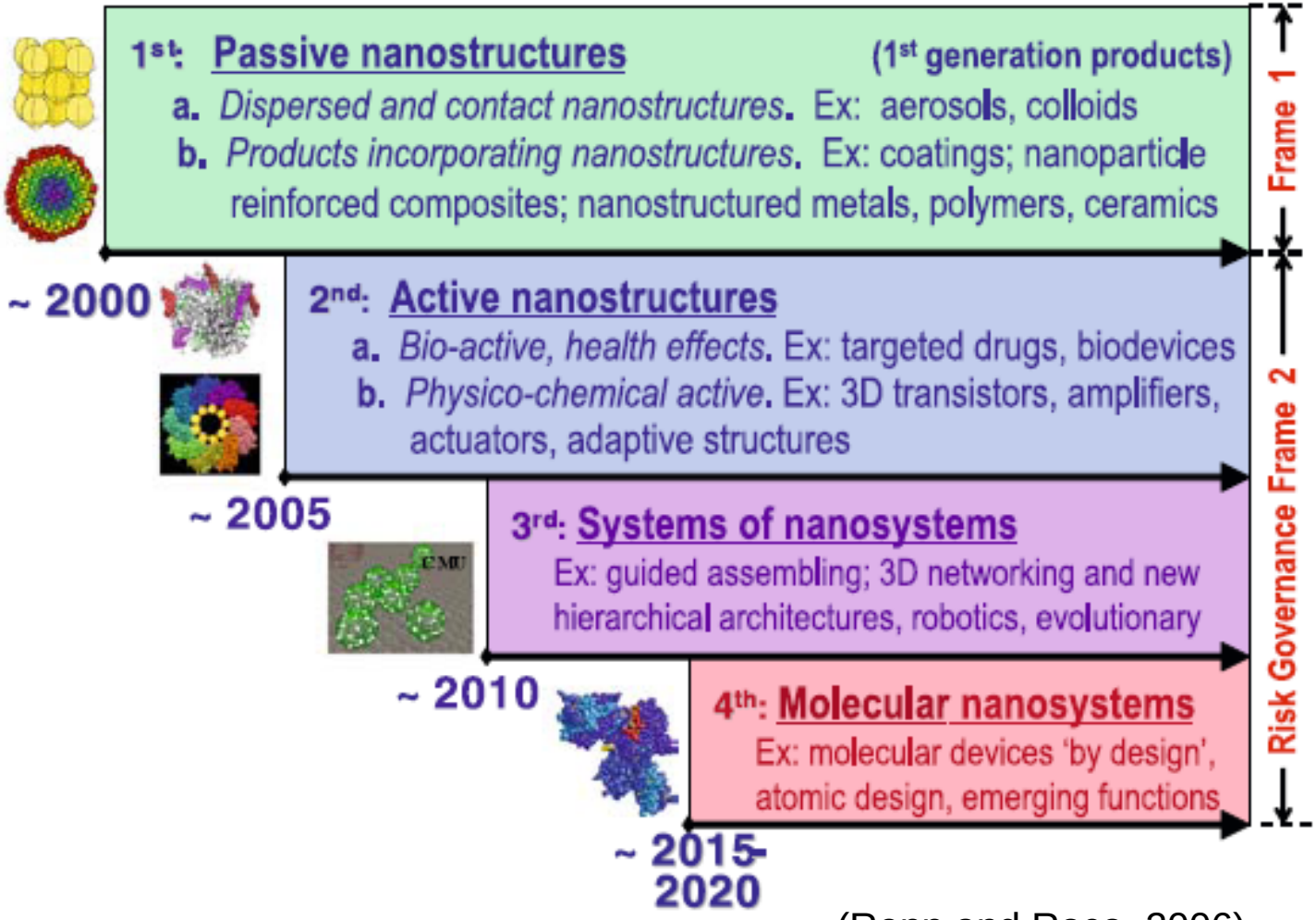
Framework

- Nanotechnologies create new oportunities in energy, materials, health, electronics, information technologies areas and in many other domains

- Major investments are beeing made in new nanomaterials and aplications

- The number of nanotechnology-based products available to consumers in March 2011 was about 1300 (WWICS, 2011)

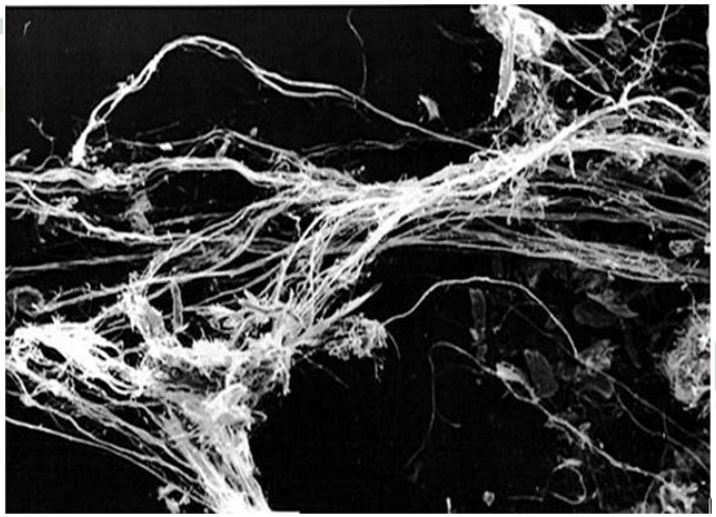
Framework

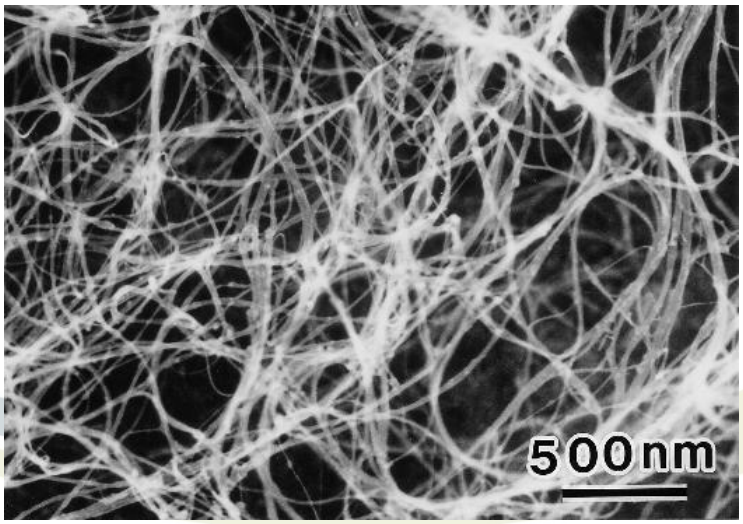


(Renn and Roco, 2006)

Framework

- There are doubts concerning the harmful effects for human health and the environment
- In this climate of uncertainty the risk management it is vital, in order to sustain the economical development without jeopardise the environment and human health





Harmful health effects

- Research performed during the last decade reveal ENM harmful health effects (Schulte et al., 2008)

Reference (in review)	Effect	Nanoparticle
Shvedova et al, 2005; Elder et al, 2006; Mercer et al, 2008	**Deposit in the alveoli**	Single-walled carbon nanotubes; ultrafine TiO_2; ultrafine carbon black
Mercer et al, 2008; Oberdörster et al, 1994	**Enter alveolar walls**	Single-walled carbon nanotubes; ultrafine TiO_2
Bermudez et al, 2004; Shvedova et al, 2005; Mercer et al, 2008	**Produce fibrosis**	Ultrafine TiO_2; single-walled carbon nanotubes
Nikula et al, 1995; Heinrich et al, 1995	**Produce tumours**	Ultrafine TiO_2; ultrafine carbon black
Shvedova et al, 2005	**Induce granulomas**	Single-walled carbon nanotubes
Takenaka et al, 2001; Oberdörster et al, 2002; Geiser et al, 2005	**Enter and move through circulatory system**	Ultrafine TiO_2; silver and elemental carbon (^{13}C)
Takenaka et al, 2001; Oberdörster et al, 2002; Geiser et al, 2005	**Enter various organs**	Ultrafine TiO_2; silver and elemental carbon (^{13}C)
Porter et al, 2007; Porter et al, 2007	**Enter cell nuclei**	Single-walled carbon nanotubes; fullerenes (C_{60})
Elder et al, 2006; Oberdörster et al, 2004	**Move from nose to brain**	Ultrafine elemental carbon (^{13}C); ultrafine manganese oxide
Ryman-Rasmussen et al 2006	**Penetrate epidermis**	Quantum dots

Nanomaterials hazard tests

- Nanomaterials base set of hazard tests including physiochemical, toxicity and ecotoxicity characterization (Warheit et al., 2007)

Nanomaterial physiochemical characterization	Mammalian hazard tests	Genotoxicity tests	Aquatic screening battery
Size and size distribution **Crystal structure** **Chemical composition** **Surface reactivity**	**Pulmonary bioassay** **Skin irritation** **Skin sensitization** **Acute oral toxicity** **Eye irritation**	**Bacterial reverse mutation** **Chromosomal aberration**	**Rainbow trout** **Daphnia** **Green algae**

- Scientific Committee on Emerging and Newly Identified Health Risks propose additional tests, in particular chemical reactivity tests and, depending on the nature of the nanoparticles, **photoactivation capabilities** and the **potential to generate active oxygen** (SCENIHR, 2009)

Risk assessment

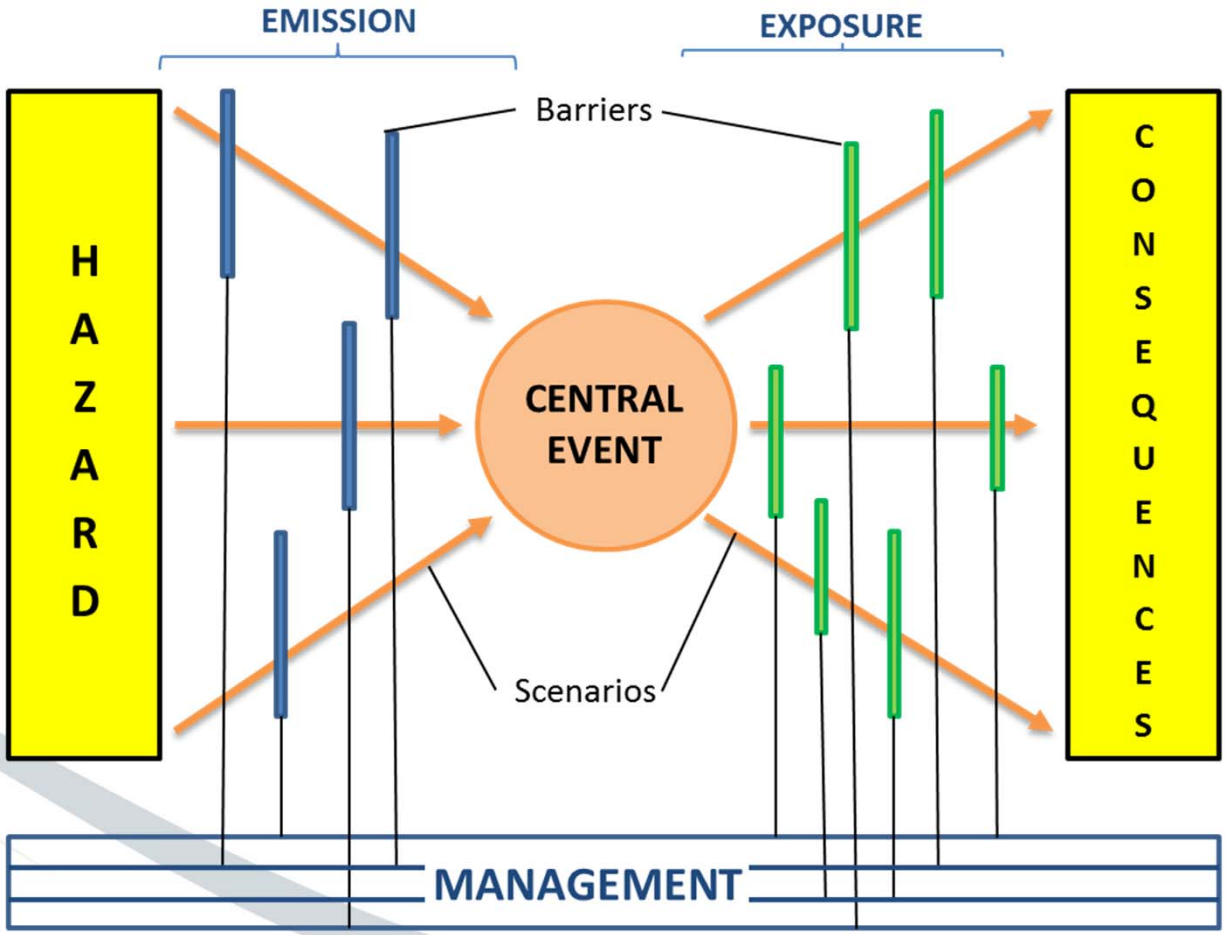
- Occupational Hygiene traditional approach it is not yet possible (Maynard, 2006; Schulte et al., 2010), although some advances (Broekhuizen et al., 2012)
- Qualitative methods are presented as an valid alternative for nanoparticles exposure risk assessment:
  - Experts judgement variants (Murashov and Howard, 2009; Kandlikar et al., 2006) e multi-criteria decision analysis (Linkov et al., 2007)
  - CB Nanotool (Paik, Zalk and Swuste, 2008; Maynard, 2007; Schulte et al., 2010; Beaudrie and Kandlikar, 2011)
  - Stoffenmanager Nano (Van Duuren-Stuurman et al., 2011)
  - Nanosafer (The UK NanoSafety Partnership Group, 2012)
  - ANSES Nano (Ostiguy et al., 2010)

Design analysis approach

- Some authors have been defending the need for methodologies that deal with the nanotechnologies risks based on the processes or products design (Fleury et al., 2011; Amyotte, 2011), referring, in particular, the “Design for Safer Nanotechnology” (Morose, 2010)

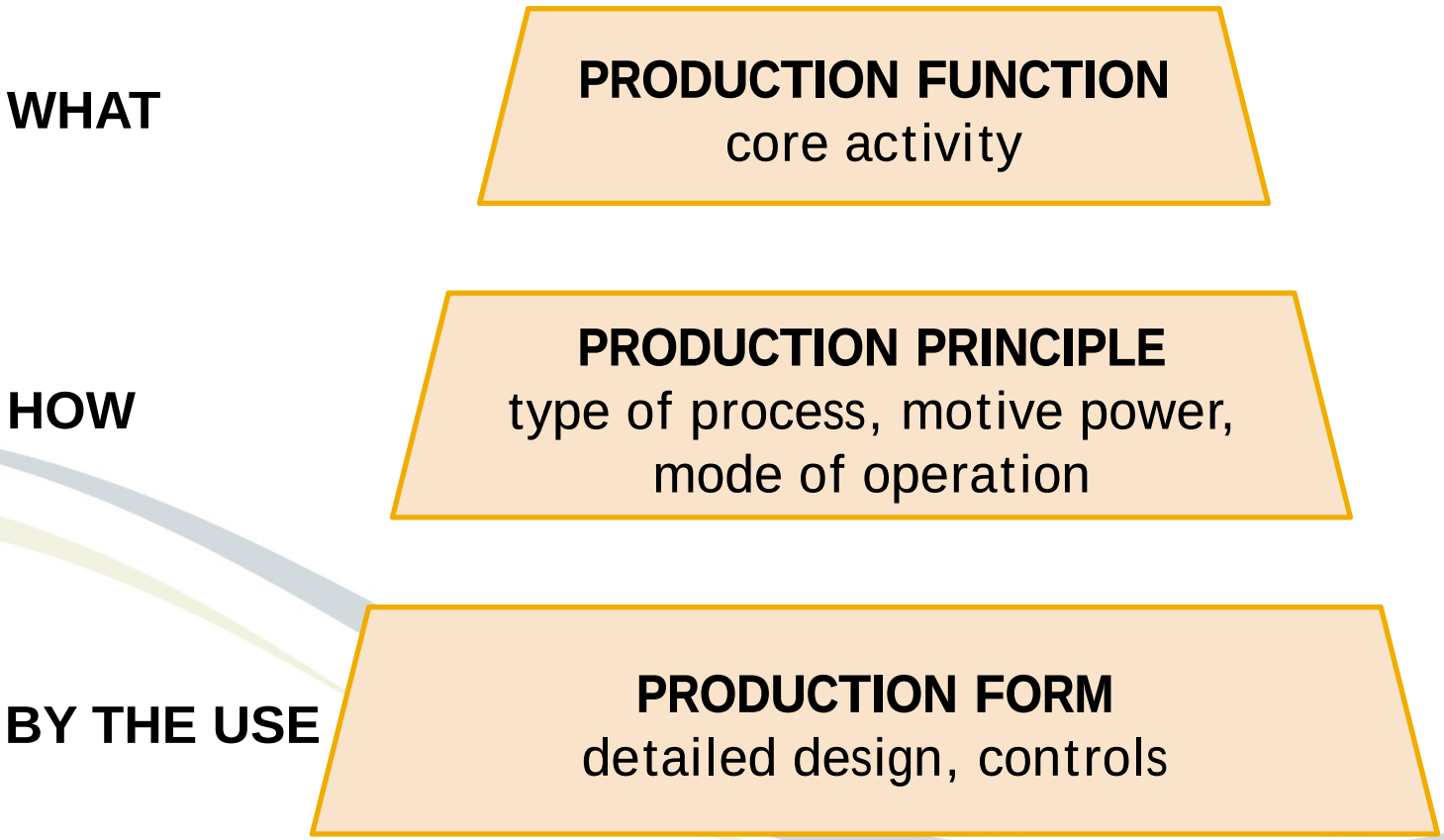
- Systematic approach towards solutions (Swuste, 1996) based on three complementary elements:
  - Hazard process model;
  - Design analysis;
  - Problem-solving cycle.

Exposure bow-tie model

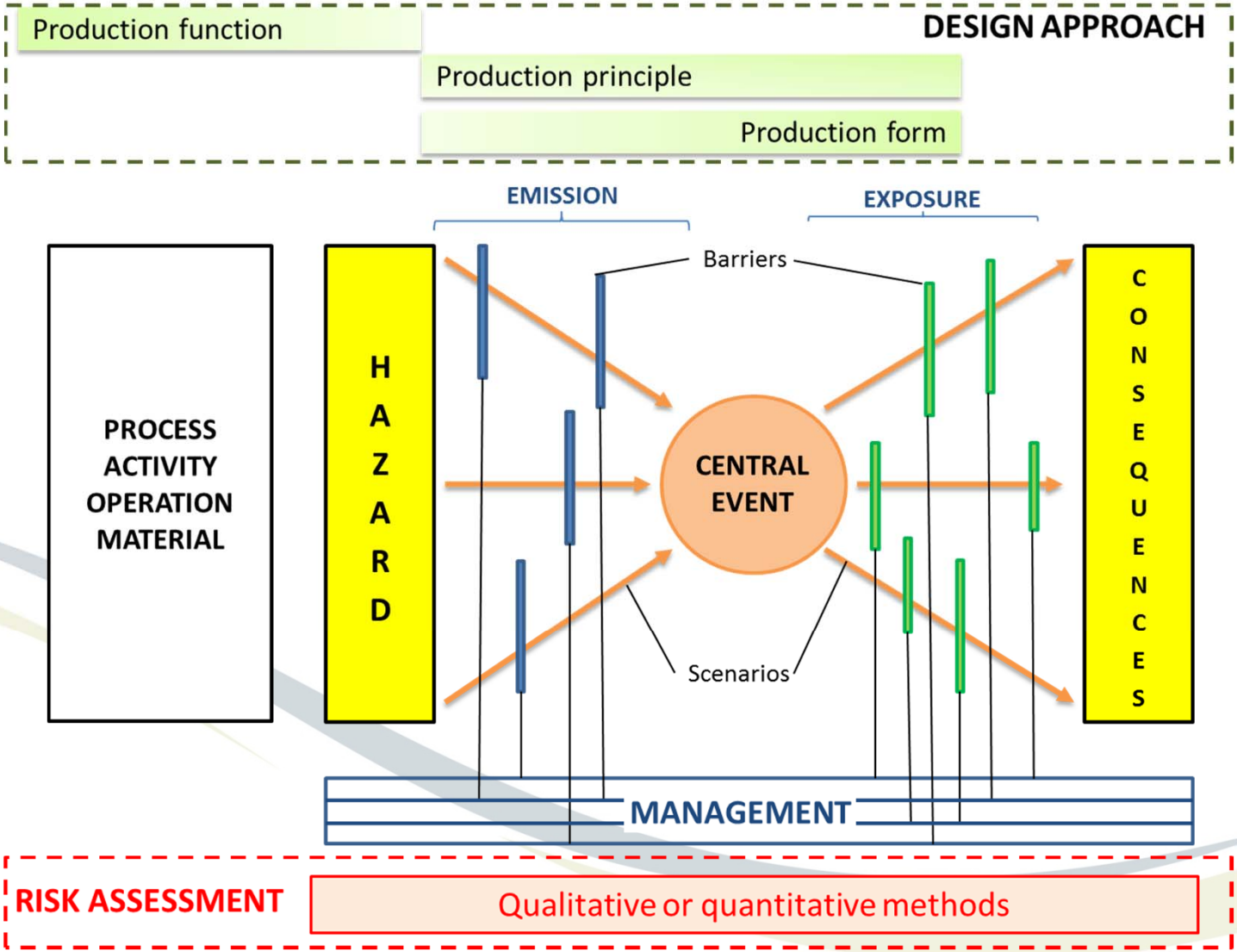


RISK ASSESSMENT — Qualitative or quantitative methods

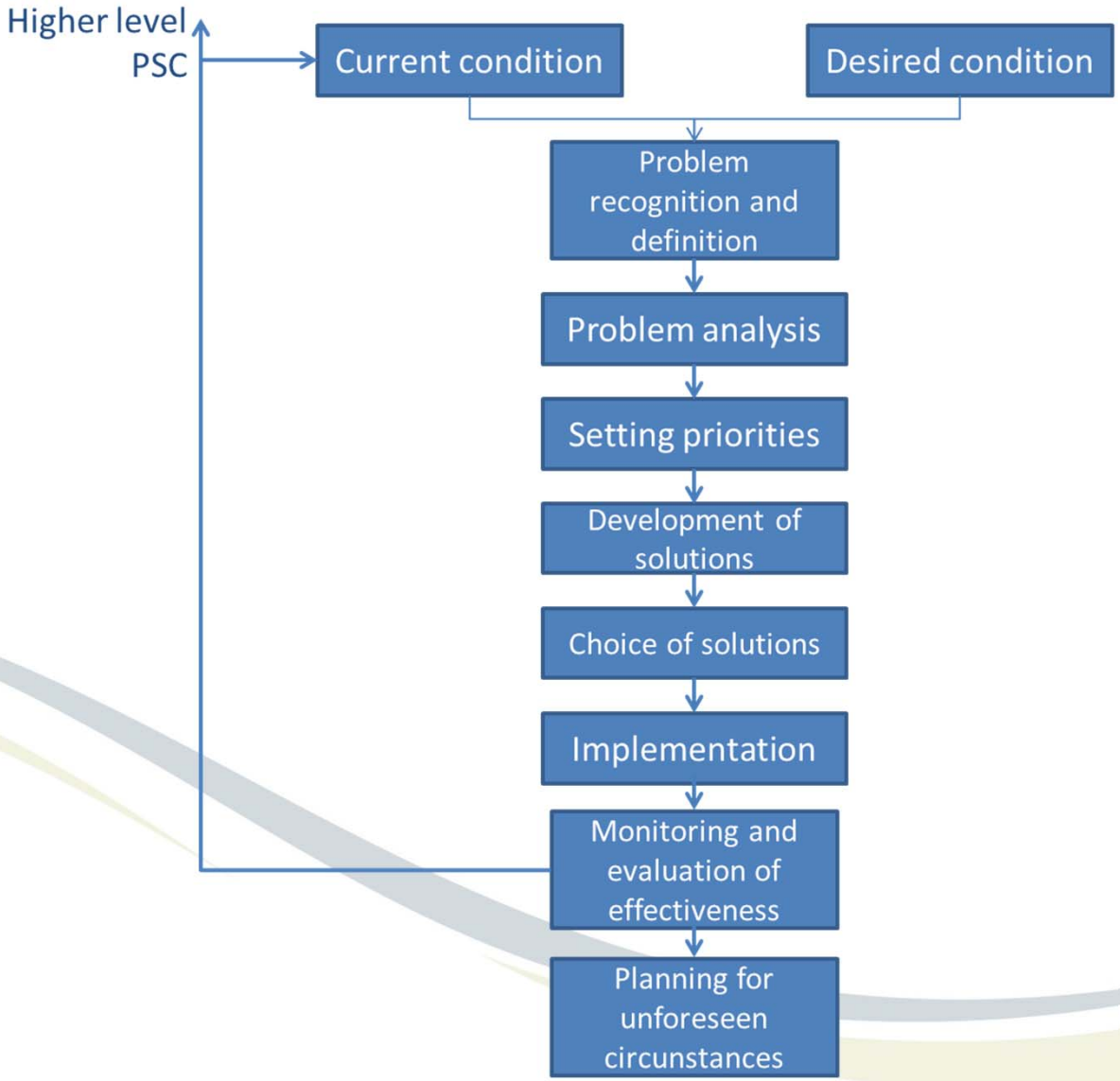
Design analysis approach



Exposure bow-tie model



Problem-solving cycle



Conclusions

- Results from toxicological tests show harmful effects from the nanoparticles;
- Nanoparticles characterization battery tests are already available;
- Quantitative exposure assessment methods and exposure limit values are not yet consensual;
- Qualitative exposure risk assessment methods are in use and gather interest from the experts;
- The design approach to safety is presented as an alternative to develop safer product and processes in the nanotechnologies field.

Research

- There is an opportunity to develop additional research in this area in order to confirm the applicability of the qualitative risk assessment and the design analysis approach in the nanoparticles occupational hygiene field

- It is intended to apply this methods in different work environments in order to develop a strategy to deal with nanomaterials occupational risks, based on the qualitative risk assessment and risk control

THANKS FOR YOUR ATENTION!

Anything is edible if it is chopped finely enough?