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Identification and development of nano-materials for water treatment

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- ENMIX: European Nanoporous Materials Institute of Excellence (12 core and one associated partners)

- Successor organisation of the FP6 NoE "INSIDE-PORES"

- Four ENMIX Partners participate in ChemWater:
  - University of Antwerp (Belgium)
  - University of Alicante (Spain)
  - CERTH/CPERI (Greece)
  - SINTEF (Norway) - Coordination

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- **What are nano-materials?**
  - **Nano-materials comprise a diverse set of substances that are defined by the particle size: They have at least one dimension that measures less than 100 nm (compare: The width of human hair is about 80.000 nm).**
  - **Nanoparticles exist in nature (like clays, amorphous silica, iron oxyhydroxides, viruses), but engineered nano-materials (like nano-Ag, nano-titania, cerium oxide, fullerenes, carbon nanotubes and quantum dots) have captured the most attention in recent years.**
  - **Their minute size bestows nano-materials with properties that differ from those of larger particles:**
    - **Large surface-area-to-mass ratio**
    - **Increased reaction kinetics**
    - **Optical and electrical properties**

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- **Commercial uses of nano-materials have developed quickly (from cosmetics to medicine), and the global production of nano-materials is expected to increase exponentially.**

- **In recent years, manufacture and use of nano-materials has spanned a wide range of products.**

- **However, our understanding of the potential risks (health and environmental effects) posed by nano-materials hasn't increased as rapidly as research has regarding possible applications.**

(American Water Works Association)

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- **Overview:**
- **Identification and development of nano-materials for water treatment:**
  - **Photo-catalysts for the removal of water pollutants and active under visible light irradiation (not only UV light)**
  - **Catalysts/adsorbents for the removal of arsenic and reduction of nitrates/nitrites in water**
  - **Materials for water desalination: Reverse osmosis and nano- and/or micro-filtration**
  - **Adsorbents/Adsorption properties of graphenes and MOFs**
  - **Development of high surface to volume carriers for bacteria**
  - **Antifouling: New catalysts combined with oxidants (titania/ozone)**
- **Emerging Water Treatment Technologies and devices for water monitoring**
  - **Removal of nano-materials from drinking water**
  - **Nanosensors**

- **Photo-catalysts for the removal of water pollutants and active under visible light irradiation (not only UV light)**
  - **Titania is a promising photo-catalyst for water treatment due to its high removal efficiency and rapid degradation rates for organic compounds.**
  - **Use of titania is especially attractive because of growing concerns about persistent pollutants and emerging pollutants, like pesticides.**
  - **UV-based and visible-light-activated nano-titania films might degrade cyanotoxins and could inactivate various microorganisms.**

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- Catalysts/adsorbents for the removal of arsenic and reduction of nitrates/nitrites in water
  - Removal of arsenic from water :
    - Titanium-based nano-materials
    - Ion-exchange resin impregnated with nano-scale iron hydroxide
    - Titanate nanofibers
    - Iron-oxide coated sand

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- Materials for water desalination: Reverse osmosis and nano- and/or micro-filtration:
  - Low-pressure membrane filtration, such as micro- and ultra-filtration, show promise for removing aggregated nanoparticles.
  - Since nano-filtration and reverse osmosis can remove inorganic and organic contaminants down to 1 nm in size, these higher-pressure membranes should also be capable of removing non-aggregated nanoparticles.
  - However, membrane application presents major challenges regarding fouling and concentrate waste treatment and disposal.

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- **Adsorbents/Adsorption properties of graphenes and MOFs**
  - **Development of nano-sorbents for metals, anions and organic compounds, covering:**
    - **Zeolites, metal organic frameworks (MOFs ?)**
    - **Carbon nanotubes, graphenes (?)**
    - **Self-assembled monolayers on mesoporous supports , which blend mesoporous ceramics with self-assembled monolayers, creating a sorbent that shows promise for removing metals and radionuclides from water.**

- Removal of nano-materials from drinking water
  - Are nanoparticles effectively removed in drinking water treatment? If yes, by what mechanism?
  - Do nanoparticles affect the removal of other substances during drinking water treatment processes or facility performance?
  - How effective are existing treatment processes, like carbon adsorption, filtration, coagulation, sedimentation and flocculation, for treating nano-materials?

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- **Nanosensors**
  - **Nano-materials (like carbon nanotubes, gold nanoparticles, quantum dots and magnetic nanoparticles) have potential as sensor components due to their unique physical, chemical and electrical properties.**
  - **Such sensors may prove valuable for water quality monitoring.**
  - **Sensors based on nanoparticles' optical properties have been used to develop sensitive and selective detectors for pollutants.**

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- **Research Needs (general - discussion)**
  - **With respect to human and ecological exposure: Information is needed concerning the concentrations of naturally occurring and engineered nanoparticles in water.**
  - **Continues development of methods to detect and characterize nano-materials is needed. Those methods must be sensitive, cost-effective and suitable for the application with complex matrices (like surface water)**
  - **Research on the fate and transport of nanoparticles in the environment and in drinking water systems is needed.**
  - **A more complete understanding of human and ecological health effects is needed, especially at environmentally relevant nanoparticle concentrations.**

- Research Needs (specific - discussion)
  - Mechanism of nanoparticles removal from drinking water.
  - Efficiency of existing treatment processes.
  - Zeolites, MOFs as adsorbents?
  - Carbon nanotubes, graphenes as adsorbents?
  - Membrane applications: Fouling and concentrate waste water treatment and disposal.
  - Do nanoparticles affect the removal of other substances during drinking water treatment processes.
  - Others …