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Measurement and characterization of engineered titanium dioxide nanoparticles in the environment

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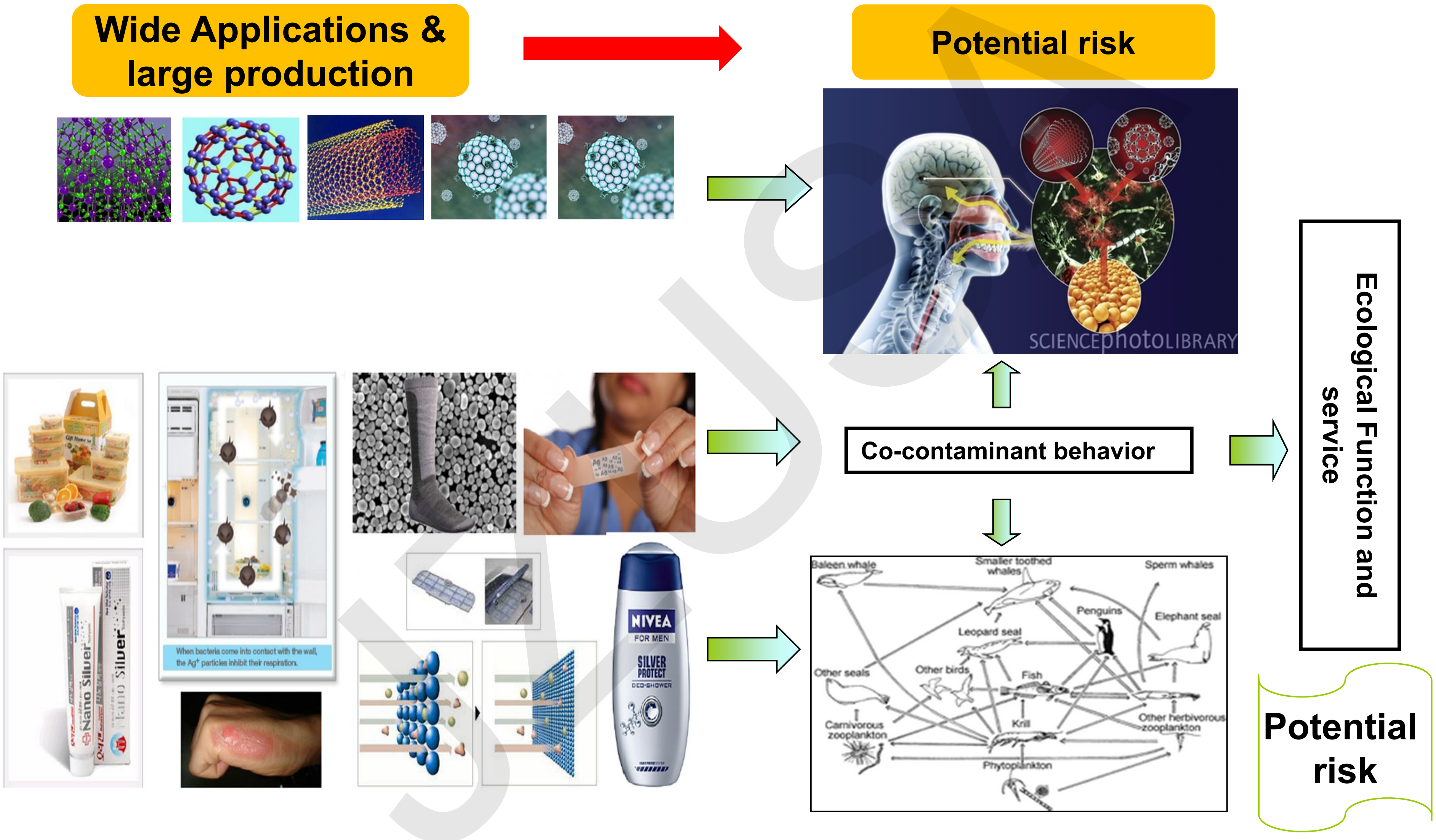
Production quantities of nano-TiO_2 in China and in the remained world

Applications → **Production**

Country	Production (ton/year)
China	1300
Europe Median and 25/75 percentile	550 (55 – 3000)
U.S.A Range	7800 – 38000
Switzerland	435
Worldwide Median and 25/75 percentile	3000 (550 – 5500)

Potential risk for human health and environment



Measured environmental nano-TiO_2 in different environmental matrixes and various analytical methods used

Potential risk → **Measured levels** → **Measured methods**

Environmental matrix	Workplace	Surface water	Wastewater treatment plants effluents	Biosolids	Sediment
Concentration	11418 – 45889 particles/cm^3 for manufacturing workplace; 9512–16337 particles/cm^3 for European construction industries	2.1 (0.55~ 6.48) μg/L	(1) <5.0 ~ 15.0 μg/L; (2) 3.2 μg/L; (3) < 25 μg/L; (4) 1.6 &1.8 μg/L	(1) 1.0 ~ 6.0 g/kg; (2) 305 mg/kg; (3) 317.4 mg/kg;	≤ 2.74 g/kg
Measurement methods used	CPC, SMPS, DC	Filtration, CFU, ICP-MS	Filtration, RDL, digestion, ICP-OES, SEM/EDX;	Filtration, digestion, ICP-MS, SEM+EDX;	Microwave aid acid digestion, ICP-MS, SEM /TEM+ EDX

Common and potential methods for separation and subsequent detection/quantification of nano-TiO_2

Separation method	Mechanism	Size range	Coupled detection/quantification technique
Filtration	Size fractionation	Down to 1 kDa	SEM, ICP-MS, ICP-OES
Microfiltration	Size-exclusion membrane	100 nm-1 μm	TEM, AFM, ICP-MS
Nanofiltration	Size-exclusion membrane	0.5 nm-1 nm	TEM, ICP-MS
Cross-flow ultrafiltration (CFU)	Size-exclusion membrane	1 nm– 1μm	TEM, SEM, ICP-MS
Dialysis	Size-exclusion membrane	0.5-100 nm	TEM, SEM
Size-exclusion chromatography (SEC)	Packed porous beads as stationary phase	0.5–10nm	ICP-MS
Ultracentrifugation (UC)	Acceleration up to $10^6 g$	100 Da–10 GDa	SEM, TEM, EDS, XRF, ICP-MS, ICP-OES
Field-flow fractionation (FFF)	Physical separation in an open tube based on an applied field	1 nm–1 μm	ICP-MS, ICP-OES
Electrophoretic mobility	Charge-size distribution along a gradient	3 nm–1 μm	ICP-MS, ICP-OES

Summary and Prospective

- **Analytical methods for engineered nanoparticles are still under development.**
- **Existing analytical techniques have to be combined, accompanied by careful sample preparation and reference materials and standardized protocols as well.**
- **Necessary to develop appropriate strategies to determine engineered titanium dioxide nanoparticles in real environments, coupled using isotope and race elements tracing techniques.**
- **Needed to develop appropriate analytical techniques for a reliable determination to facilitate relevant risk assessment of Nano-TiO_2**

Related publications

- Gao Y., **Luo Z.X**. (Corresponding author), He N.P., et al. Metallic nanoparticle production and consumption in China between 2000 and 2010 and associative aquatic environmental risk assessment. Journal of Nanoparticle Research, 2013, 15(6):1681-1690.
- **Luo Z.X**., Pan Q.K., Yan C.Z., et al. Spatial distribution, electron microscopy analysis of titanium and its correlation to heavy metals: Occurrence and sources of titanium nanomaterials in surface sediments from Xiamen Bay, China. J. Environ. Monit., 2011, 13:1046-1052.
- **Luo Z.X**., Wang Z.H., Wei Q.S., et al. Effects of engineered nano-titanium dioxide on pore surface properties and phosphorus adsorption of sediment: Its environmental implications. Journal of Hazardous Materials, 2011, 192:1364– 1369.
- **Luo Z.X.**, Chen Z., Qiu Z.Z., et al. Gold and silver nanoparticle effects on ammonia-oxidizing bacteria cultures under ammoxidation. Chemosphere, 2014, http://dx.doi.org/10.1016/j. chemosphere.2014.01.075.