Detection of titanium nanoparticles in human, animal and infant formula milk.

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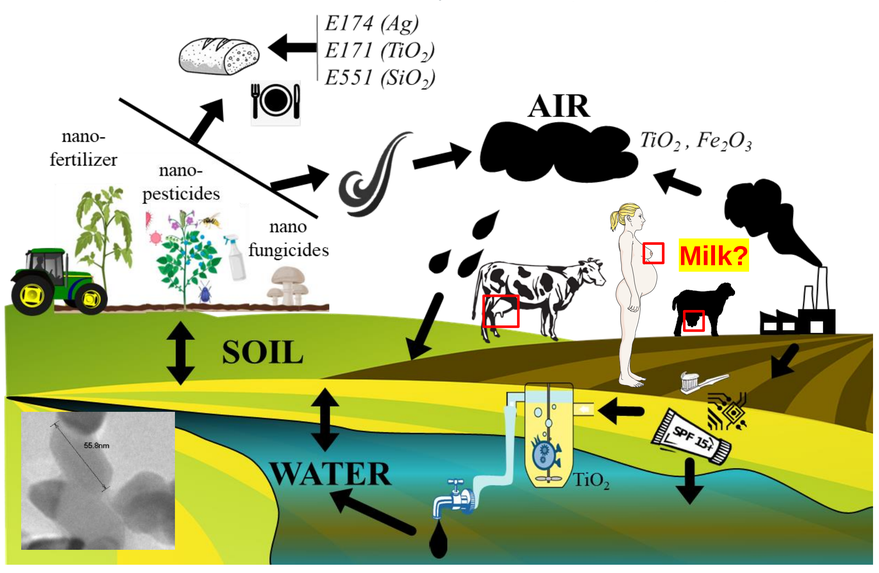
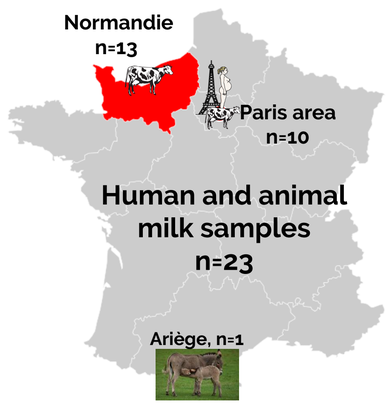
The sustainability of mammals on Earth relies on milk. During lactation, maternal exposure to metal nanoparticles (NPs) can affect offspring development and survival. Despite being banned from food applications in Europe due suspected toxicity, titanium dioxide (TiO2) NPs are still massively manufactured for countless other uses. **While contamination of ecosystems is well documented, contamination of mammals remains underexplored**. Here, we used **synchrotron X-ray fluorescence and single particle inductively coupled plasma mass spectrometry** to analyse human, animal, and infant formula milk.



Milk samples collection

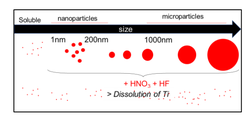


Industrial milk samples n=23

Infant formulas « IF », n=17

Powder milk « PM » France, Austria, Poland, n=6

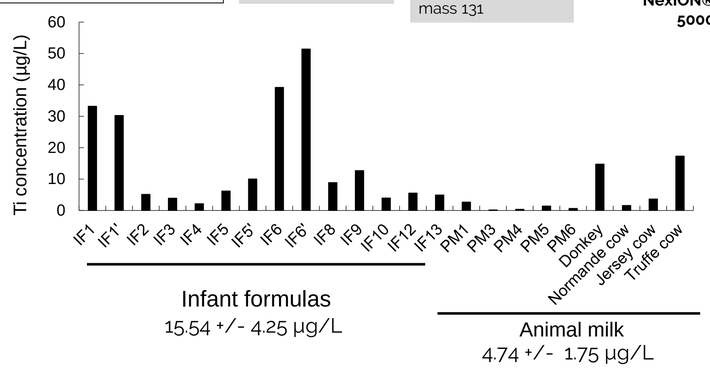
1 Titanium element is detected in mineralized milk samples



PFA MicroFlow nebulizer coupled to a 50 mL baffled cyclonic spray chamber

Reaction gas : ammoniac (0,8 mL/min), $TiNH(NH_3)_4$ complex read at mass 131

Triple quad NexION® 5000

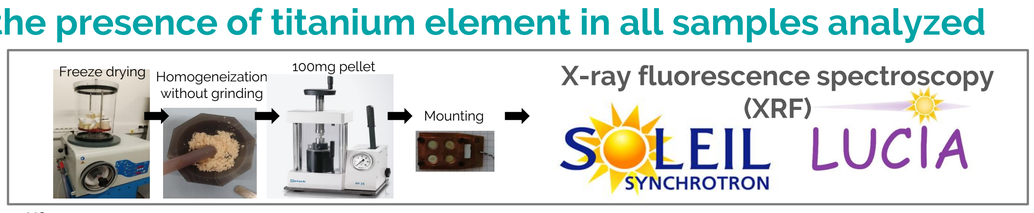


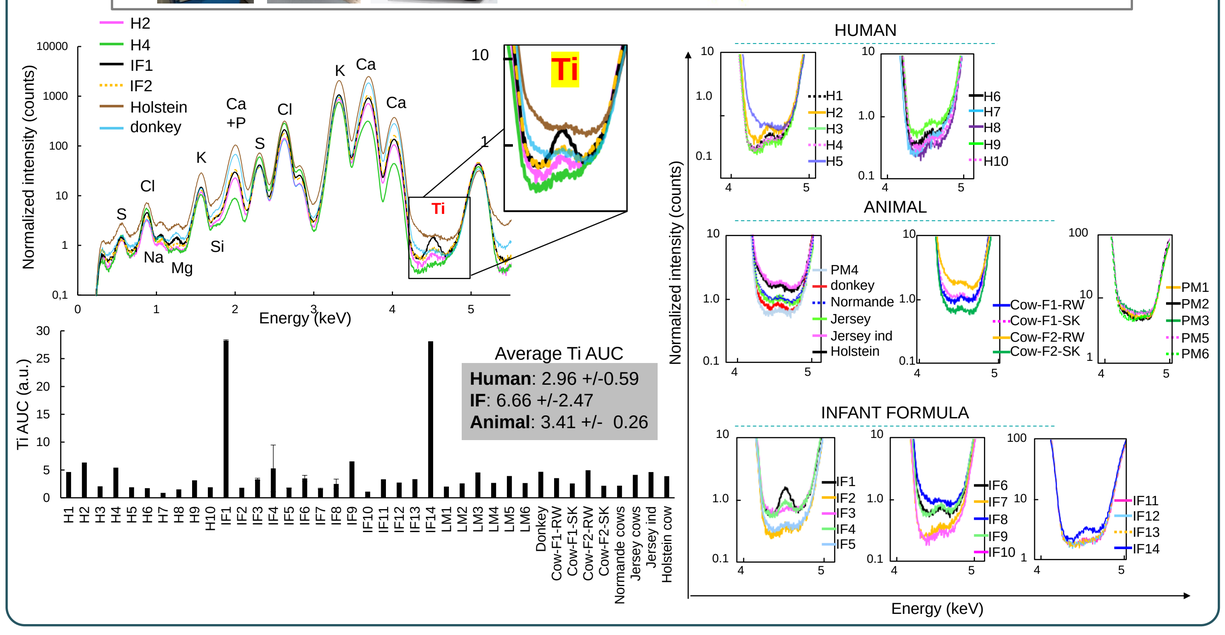
Infant formulas
15.54 +/- 4.25 µg/L

Animal milk
4.74 +/- 1.75 µg/L

Quality control : *Certified Reference Material (NCS DC 73347) prepared as milk samples: certified value 2.7 ± 0.6 µg/g, found to be 3.3 µg/g*

2 Element mapping of non mineralized milk samples revealed the presence of titanium element in all samples analyzed

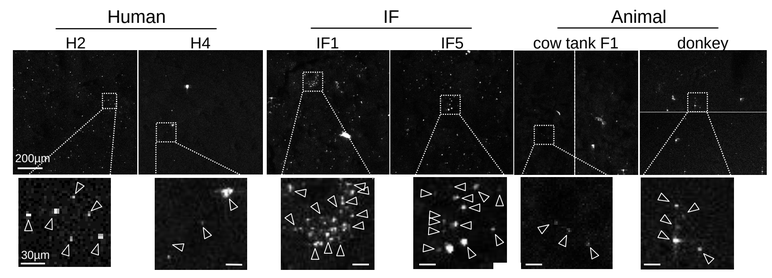


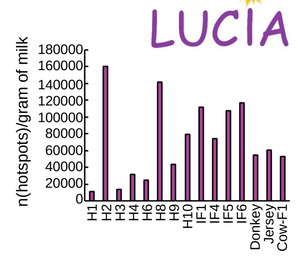


3 Titanium distributes in hotspots

Micro X-ray fluorescence spectroscopy

SOLEIL SYNCHROTRON LUCIA

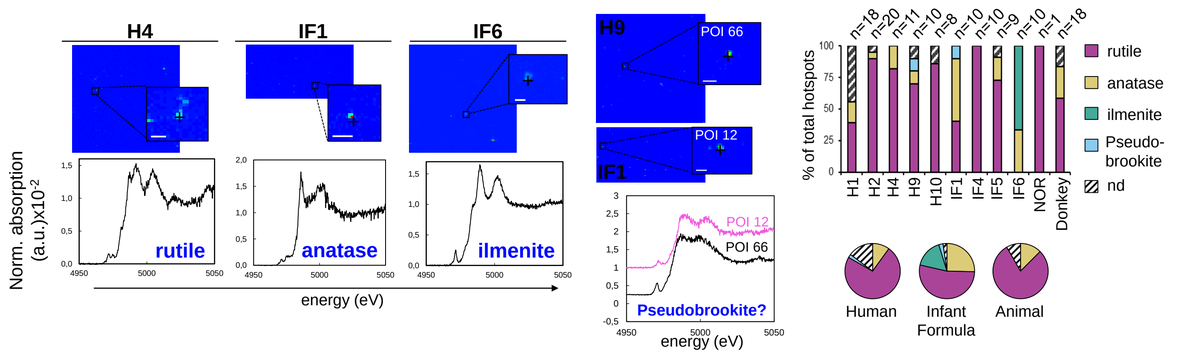




4 Milk contained various combinations of rutile TiO_2, anatase TiO_2, ilmenite Fe_2TiO_3 and titanite or pseudobrookite hotspots

SOLEIL SYNCHROTRON

micro-X-ray Absorption Near Edge Structure (µXANES)



5 Single particle ICP-MS detects titanium particles and soluble titanium in native milk samples

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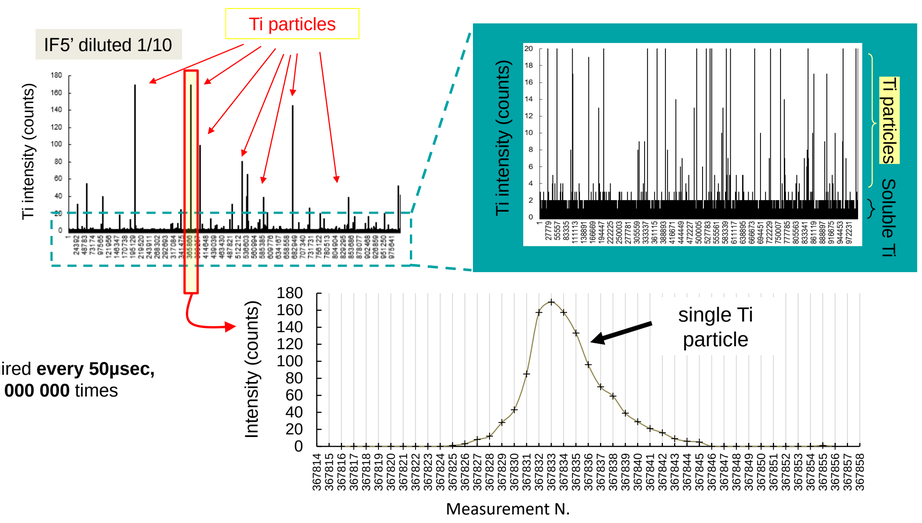
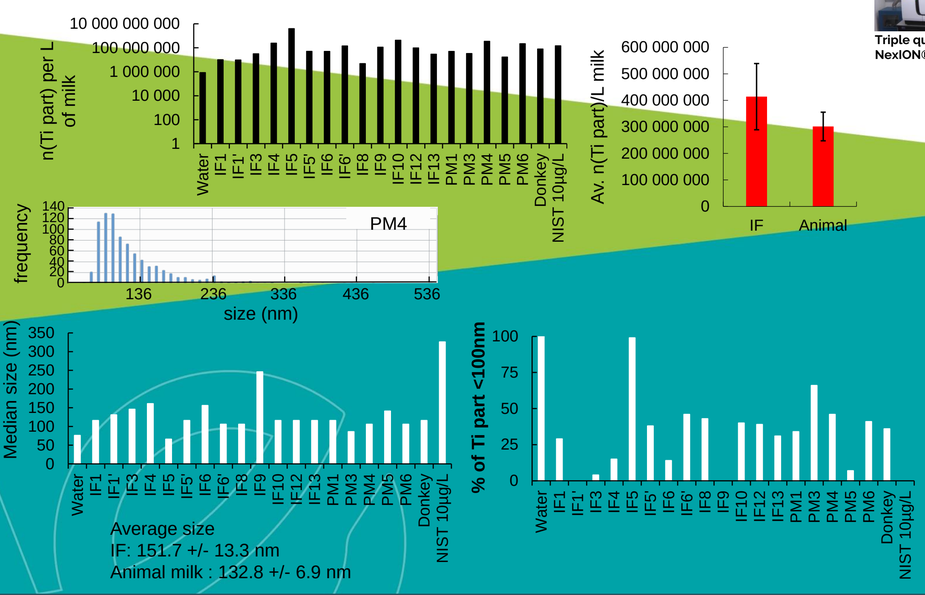


Ti signal is acquired **every 50µsec,** and repeated **1 000 000** times

6 Number, size, concentration of Ti particles and % of nanoparticles



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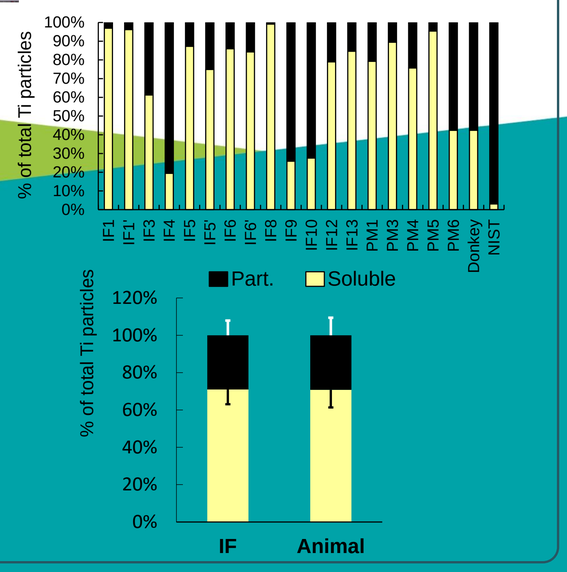
7 Respective contribution of soluble vs. particles to total Ti



Take-home messages

- All samples contained titanium micro- and **nano-particles,** regardless of the species, location, and processing.
- Concentration, sizes, and combinations varied
- **Rutile** and **anatase TiO_2, ilmenite $FeTiO_3$** and possibly **titanite $CaTiSiO_5$** or **pseudobrookite Fe_2TiO_5**.

These findings suggest that milk carries titanium-containing nanoparticles and exposes chronically neonates to this nanomaterial until weaning.

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