Gerardo Pulido-Reyes, Leonardo Magherini, Carlo Bianco,
R. Sethi, Urs von Gunten, Ralf Kaegi, Denise M. Mitrano

ASSESSMENT OF DRINKING WATER TREATMENT PROCESSES IN NANOPLASTICS REMOVAL: PILOT- SCALE AND MODELLING STUDIES

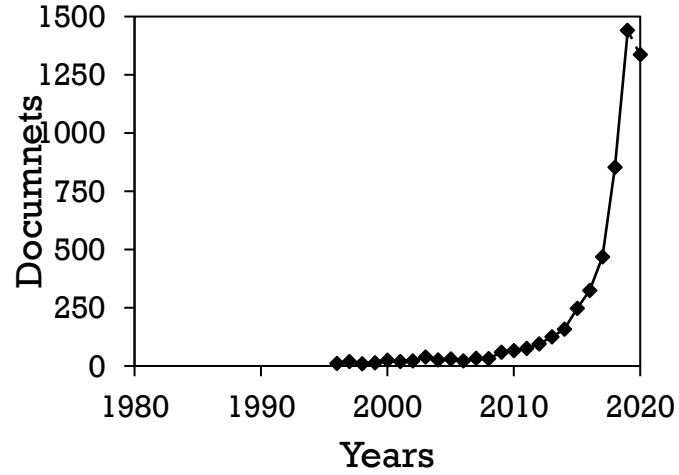
23/09/2022

Micro and nanoplastics are emerging pollutants

05/10/2020

*"… we conservatively estimate **14 million tonnes** of microplastic reside on the **ocean floor**."*

Barret et al., Microplastic Pollution in Deep-Sea Sediments From the Great Australian Bight

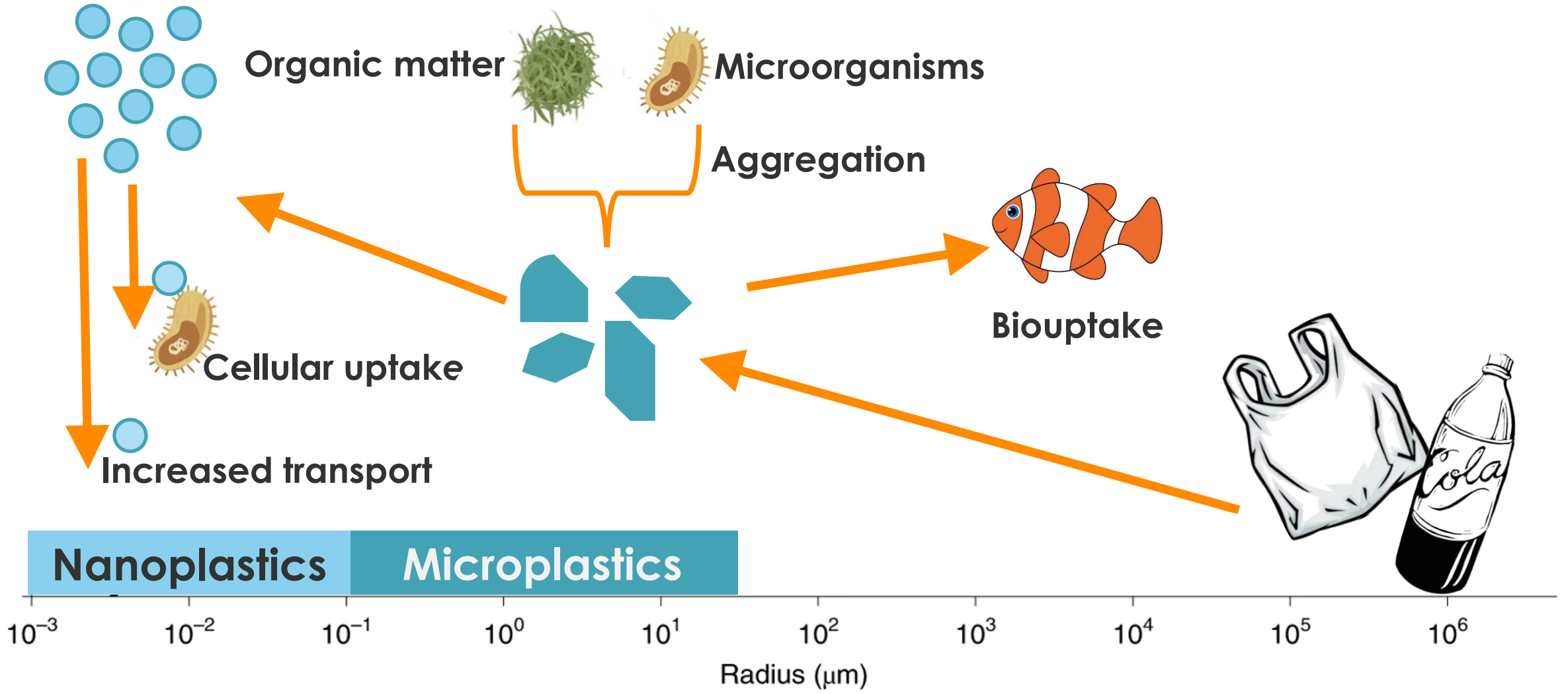


June 2009 - WWF

*"An average person could be ingesting approximately **5 grams of plastic** per **week**."*

Senathirajah et al., Estimation of the mass of microplastics ingested – A pivotal first step towards human health risk assessment

Micro and nanoplastics are emerging pollutants



Particulate plastics in water treatment systems

- Microplastics and nanoplastics are in many drinking water sources
- Can conventional drinking water treatment plant systems remove them?
- Which stages of drinking water treatment and operational conditions are most important/efficient for removal?

Simplified drinking water treatment chain

Source water

Screen (large items)

Coagulation

Ozonation

Rapid sand filtration

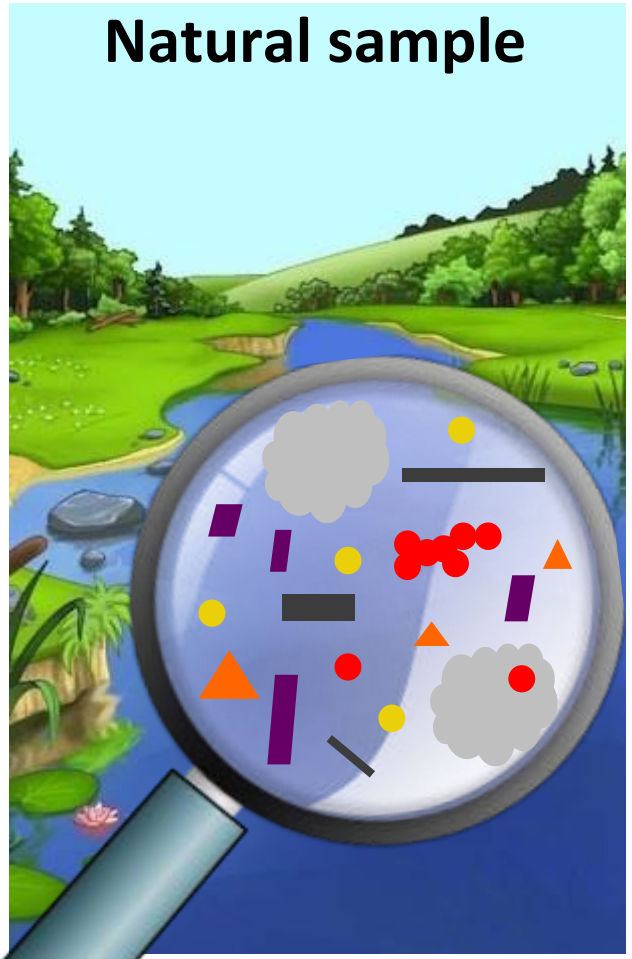
Activated carbon filtration

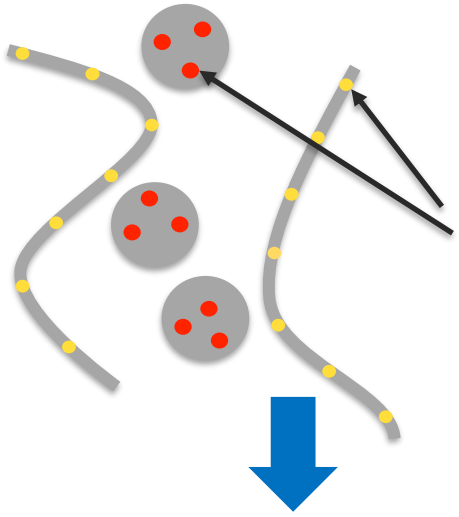
Slow sand filtration

Disinfection

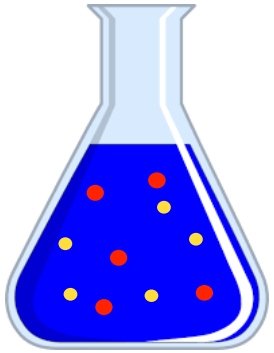
Finished drinking water

Overcoming obstacles in nano- and microplastics analysis



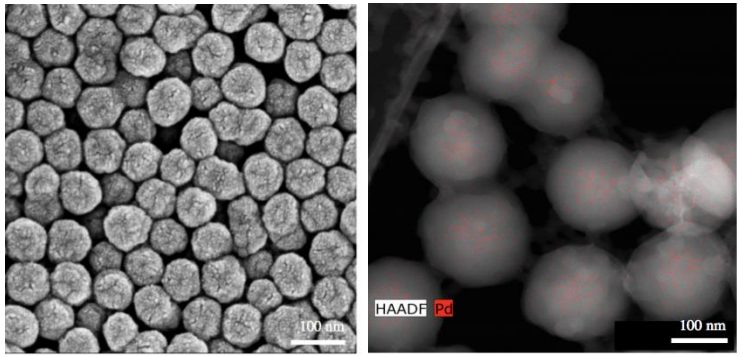


Test system



Analyze metal as proxy for plastic

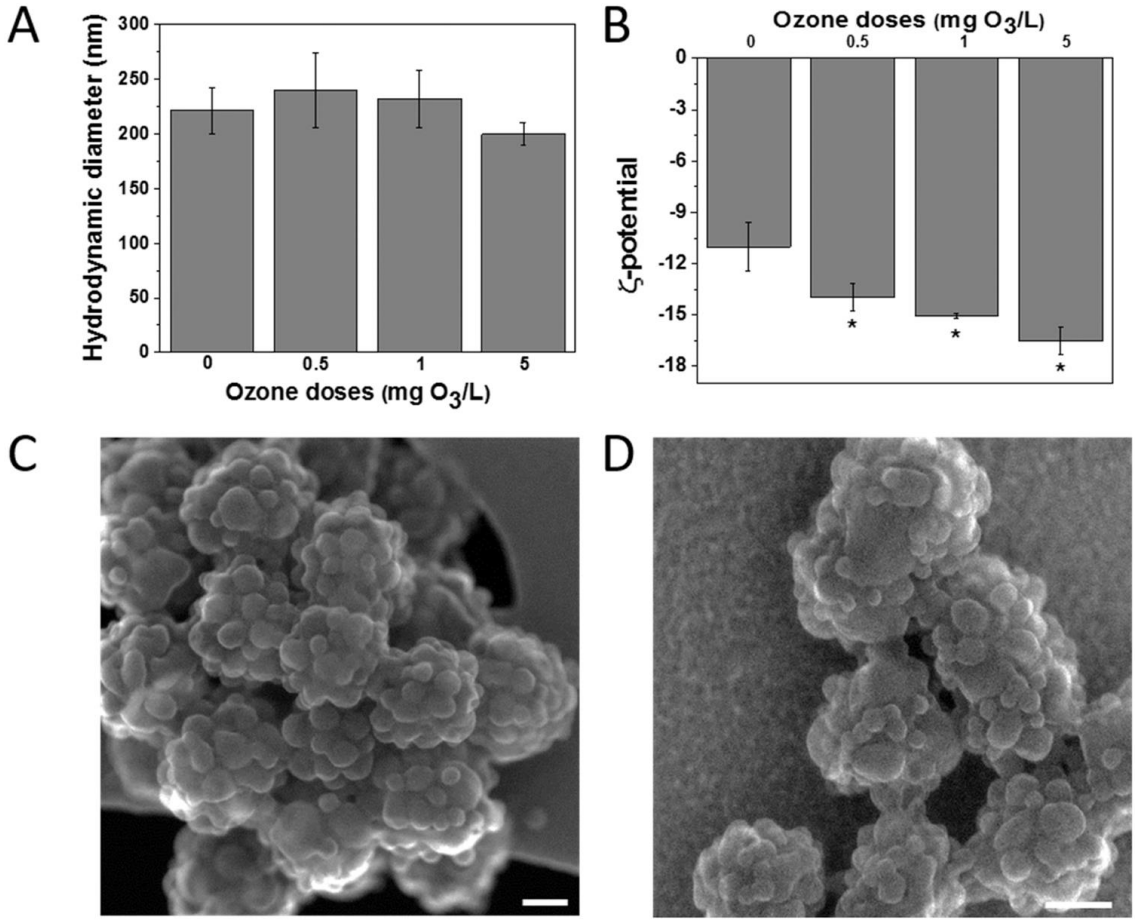
Polystyrene NP doped with Pd



Mitrano et al. Nature Nanotechnology 2019

- NPs size 160 nm
- No metal leaching over time
- Metal inside polymer, surface chemistry unaffected
- 0.3 wt% metal, density differences negligible

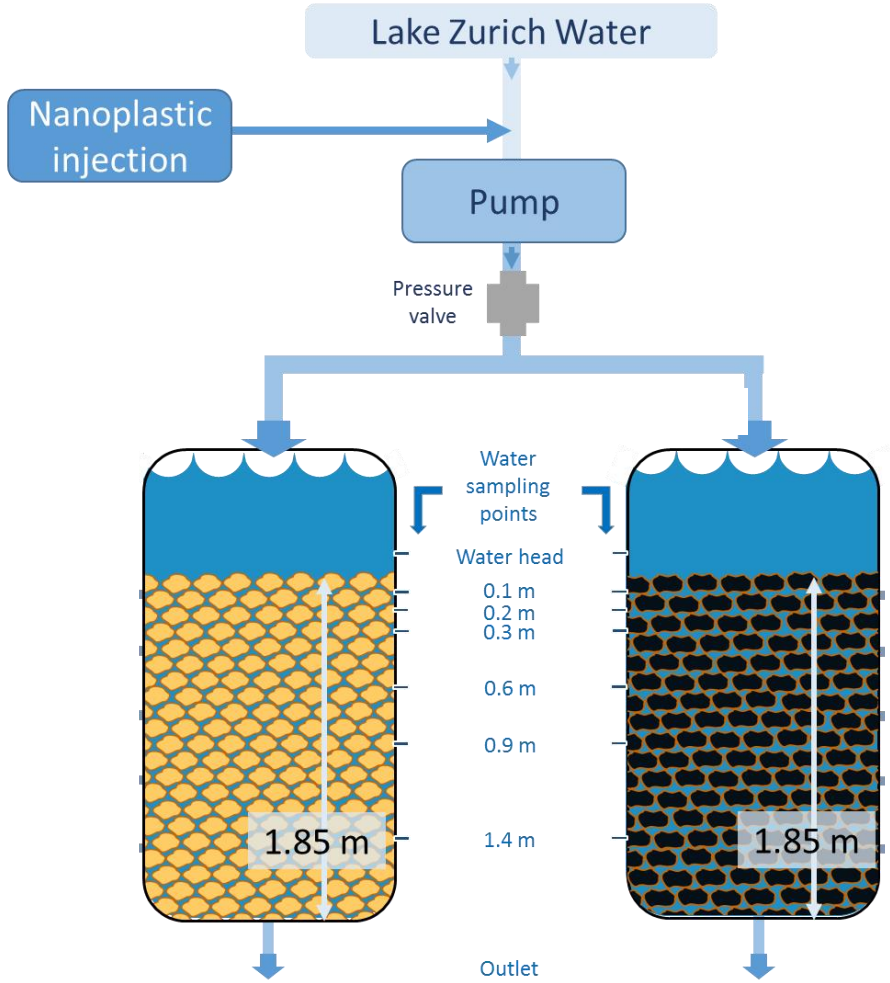
Ozonation has no effect on nanoplastics fate



- No changes in plastics size and morphology observed
- Ozonation does not significantly contribute to nanoplastics removal in DWTP

Pilot-scale drinking water treatment plant

Water supply company of Zürich



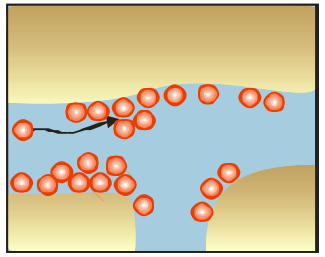
Diameter: 1.10 m
Length: 1.85 m

Modeling approach: Particle-filter interactions

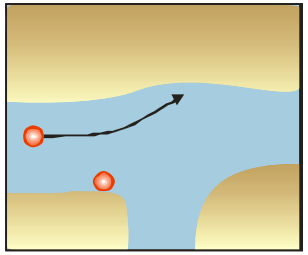
Modified transport equation accounts for interaction mechanisms:

$$\begin{cases} \dfrac{\partial}{\partial t}(\theta c) + \dfrac{\partial (r_b s)}{\partial t} + \dfrac{\partial}{\partial x}(qc) - \dfrac{\partial}{\partial x}\left(\theta D \dfrac{\partial c}{\partial x}\right) = 0 \\ \dfrac{\partial (r_b s)}{\partial t} = f(c, c_t, q, s) \end{cases}$$

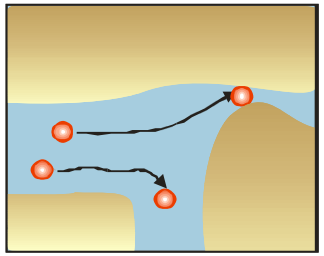
Ripening



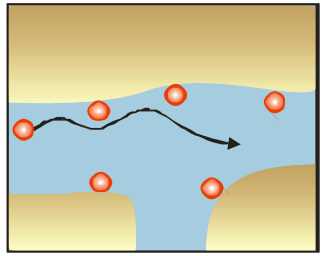
Clean bed filtration



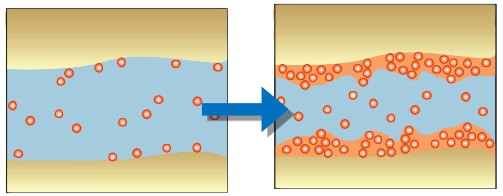
Straining



Blocking

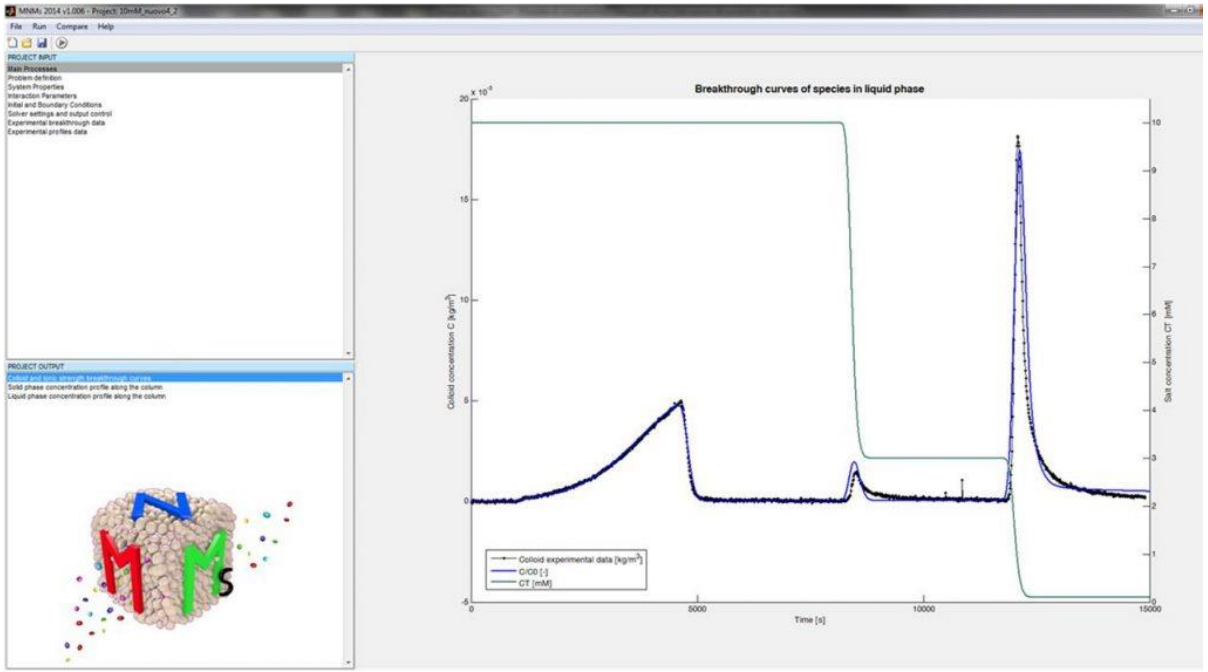


Clogging



MNMs 2022 software

MNMs = Micro- and Nano-particles transport, filtration and clogging Model – Suite



www.polito.it/groundwater/software

Licensed institutions:

1. Austrian Institute of Technology
2. University of California, Davis
3. Deltares
4. Helmhotz Centre for Environmental Research
5. Helmholtz-Zentrum Dresden
6. Helmhotz Zentrum Munchen
7. Institut de Mécanique et d'Ingénierie
8. Jacobs University Bremen
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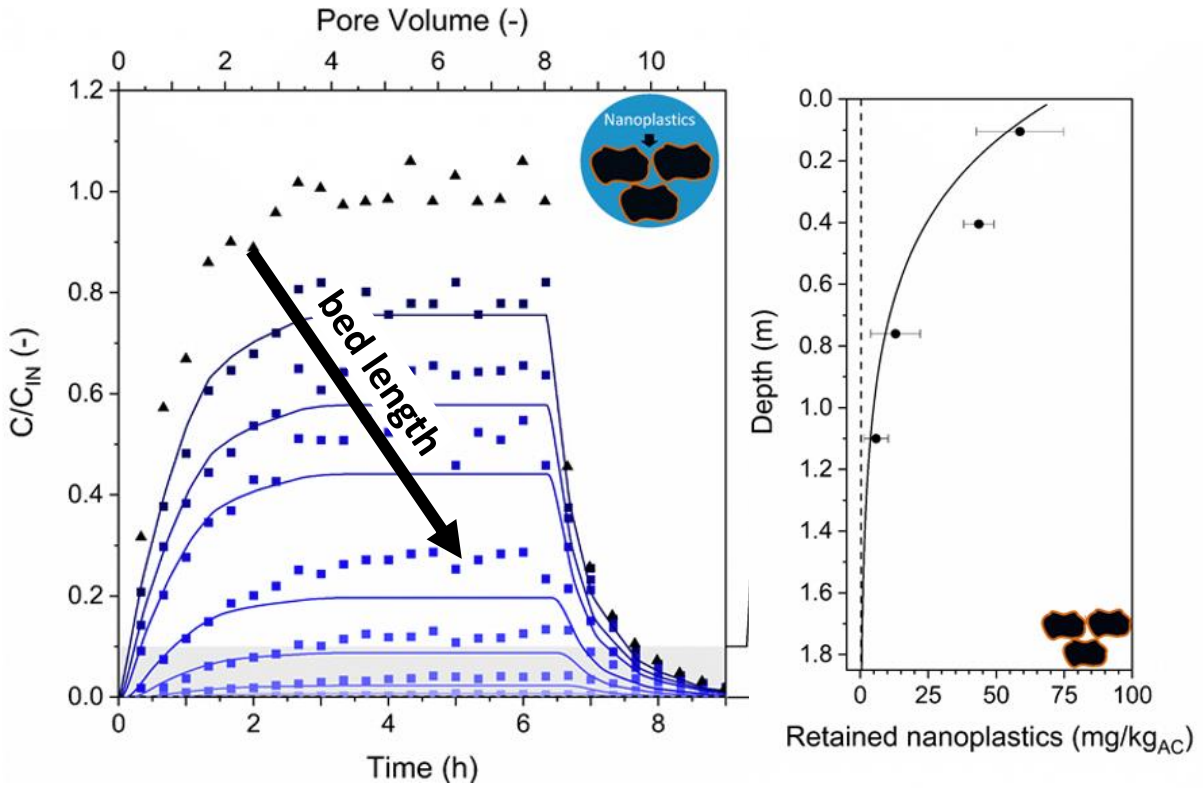
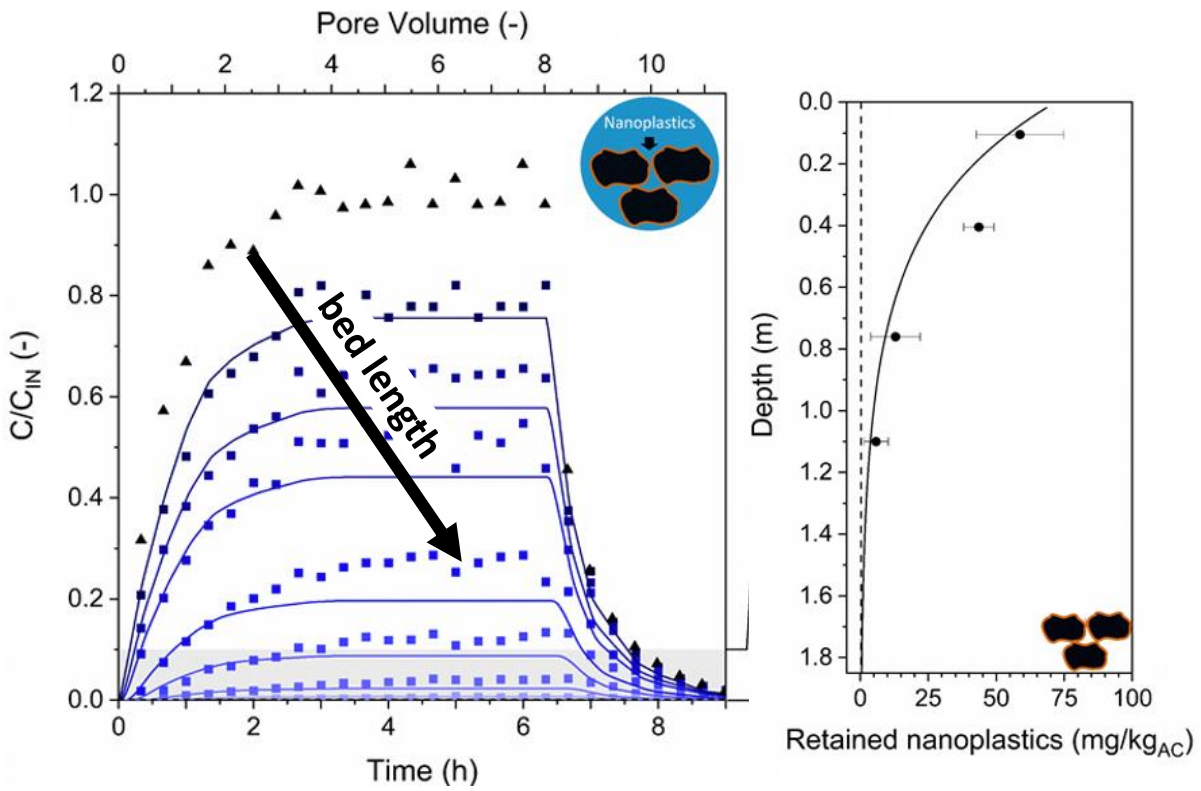
Breakthrough curves of nanoplastics in pilot scale studies

Activated carbon filter

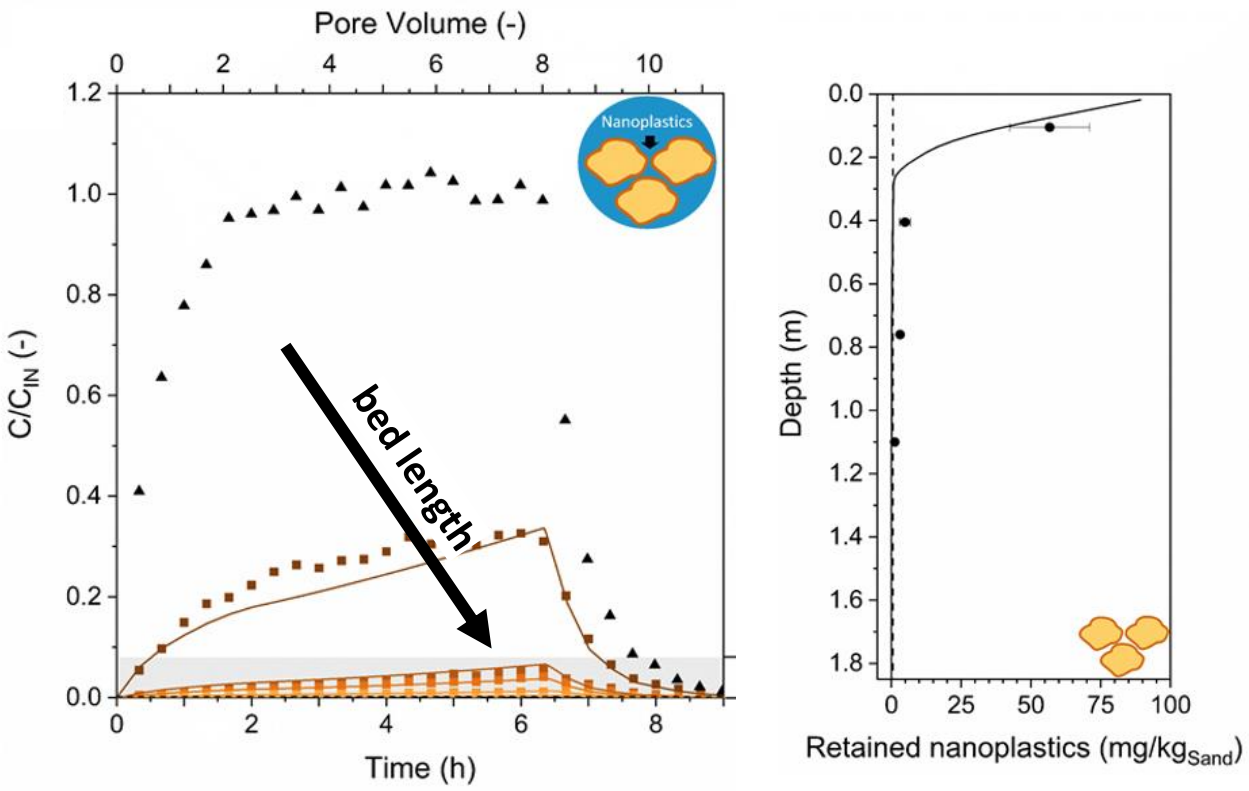


Breakthrough curves of nanoplastics in pilot scale studies

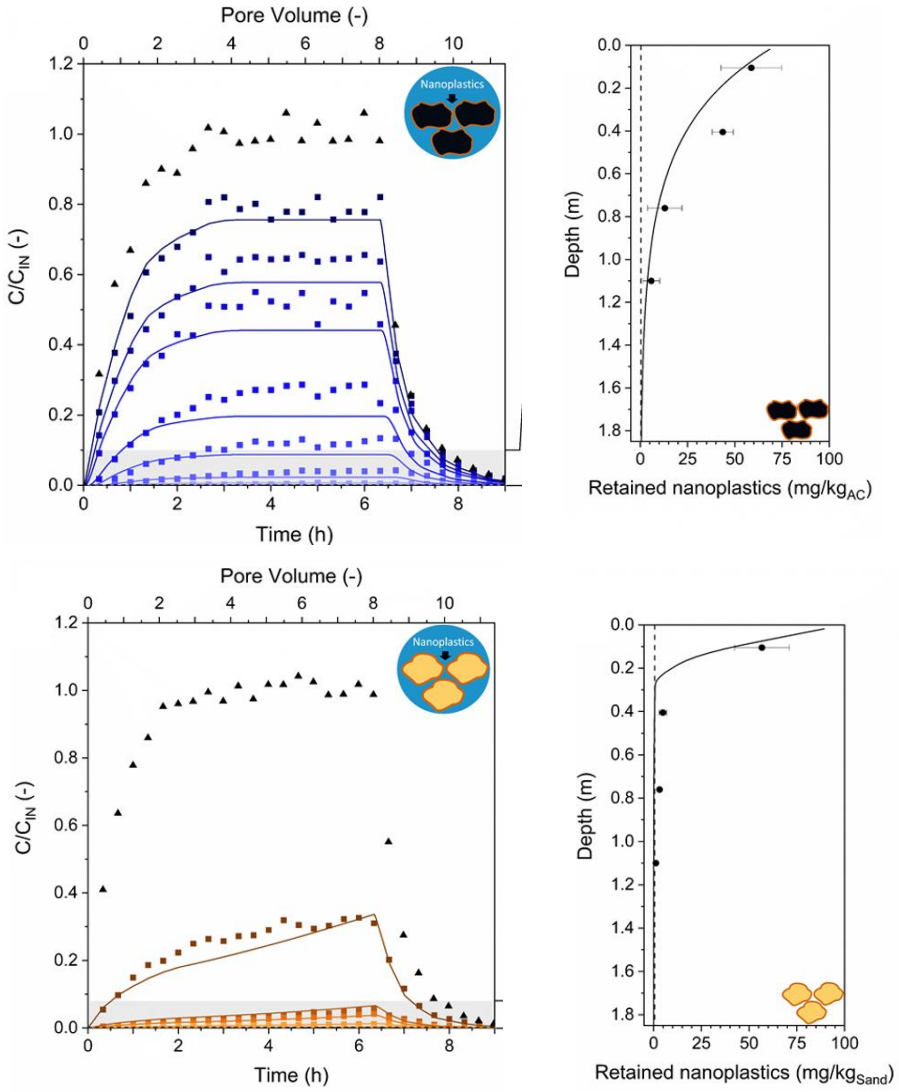
Activated carbon filter



Sand filter

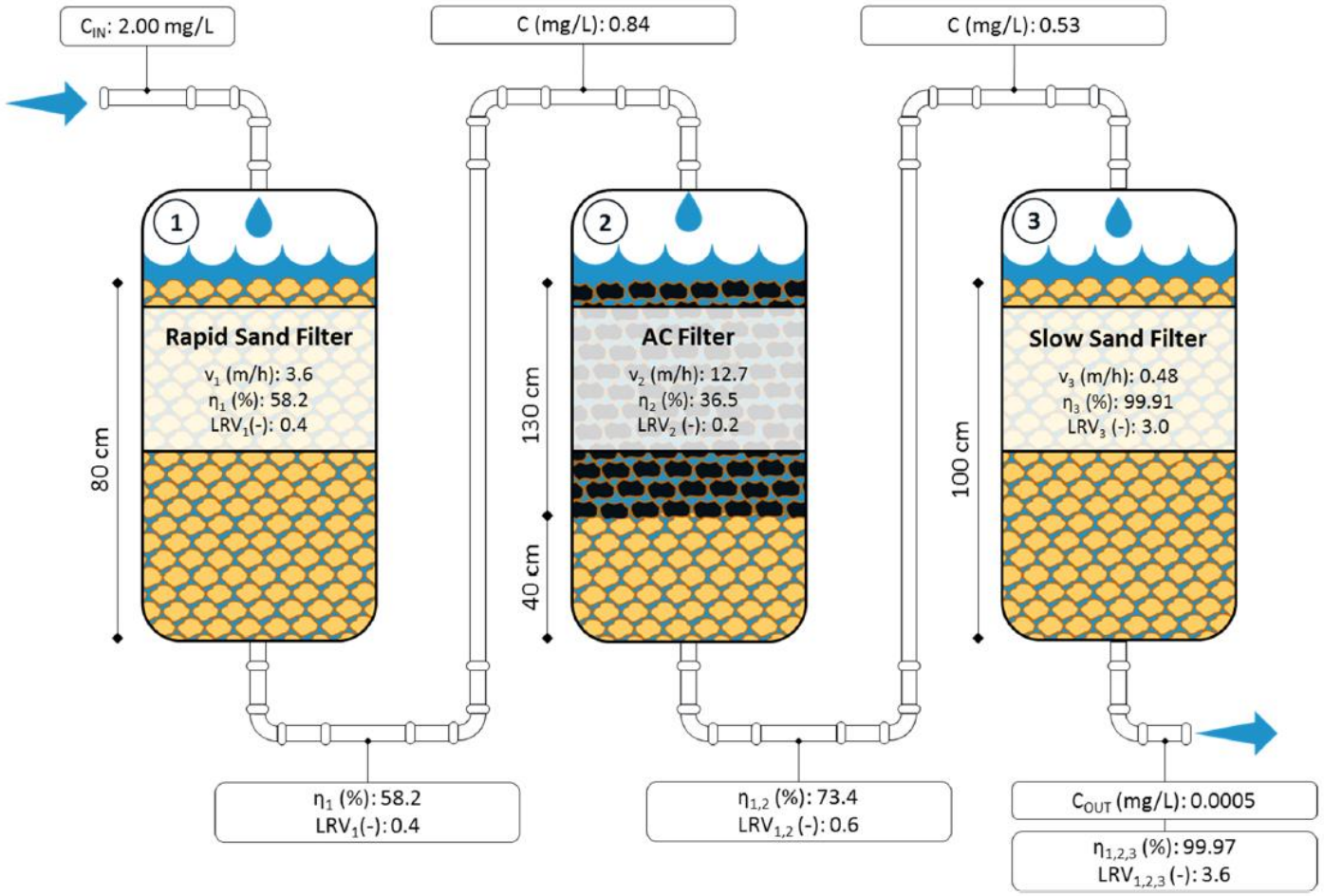


Breakthrough curves of nanoplastics in pilot scale studies



- Possibility to measure NP retention over filter depth
- Higher retention in sand than in activated carbon
- Higher retention in upper layers of sand filter, due to the presence of a biofilm
- The MNMs model properly reproduces the dynamics of nanoplastics filtration

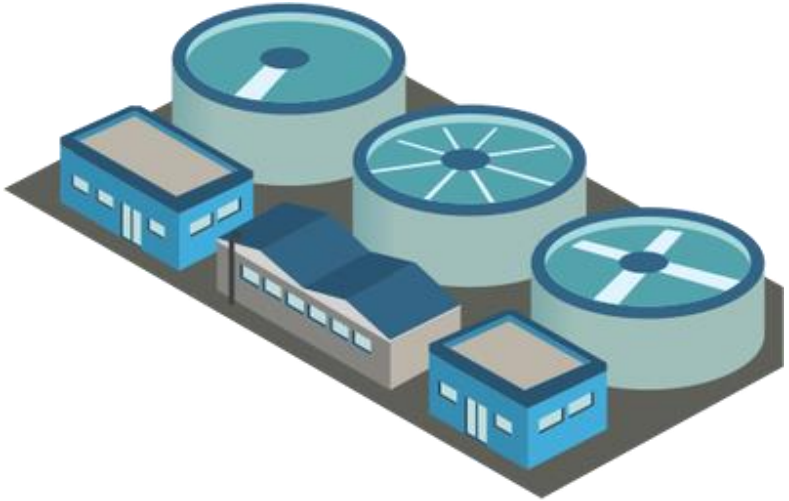
Simulated performance of a drinking water treatment chain



- NP retention parameters extracted from modeling BTC of DWTP pilot experiments used to model full-scale system
- Cumulative removal efficiencies estimated using ”unrealistically high” NP conc. to stress-test system
- High capability of filtration units: overall 3.6 log removal

Take-home messages

- Tested drinking water treatment chain significantly reduces NPs in potable water
- MNMs can help predicting large scale NPs filtration behavior
- Even higher removal anticipated in full scale drinking water treatment plants:
  - Additional treatment steps
  - More established biofilm
- Different types of NPs and drinking water treatment configurations should still be assessed



Ph.D. Carlo Bianco

carlo.bianco@polito.it

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