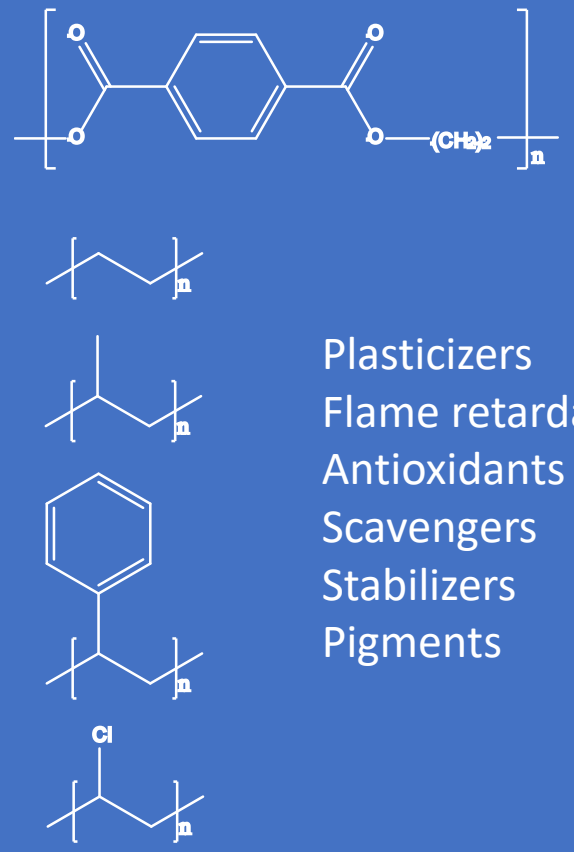
Moving towards the creation of standards for MNP research

Dr. Laurens Mandemaker, AURORA researcher, Utrecht University

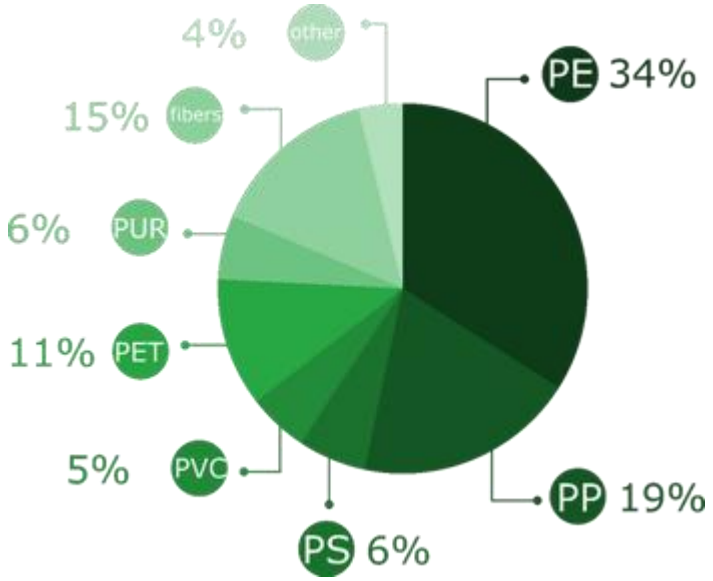
$$Risk \propto Hazard \times Exposure$$



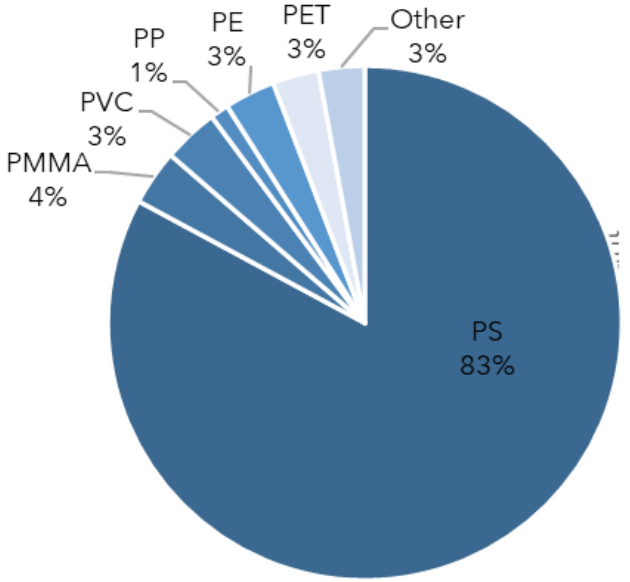
Plasticizers
Flame retardants
Antioxidants
Scavengers
Stabilizers
Pigments

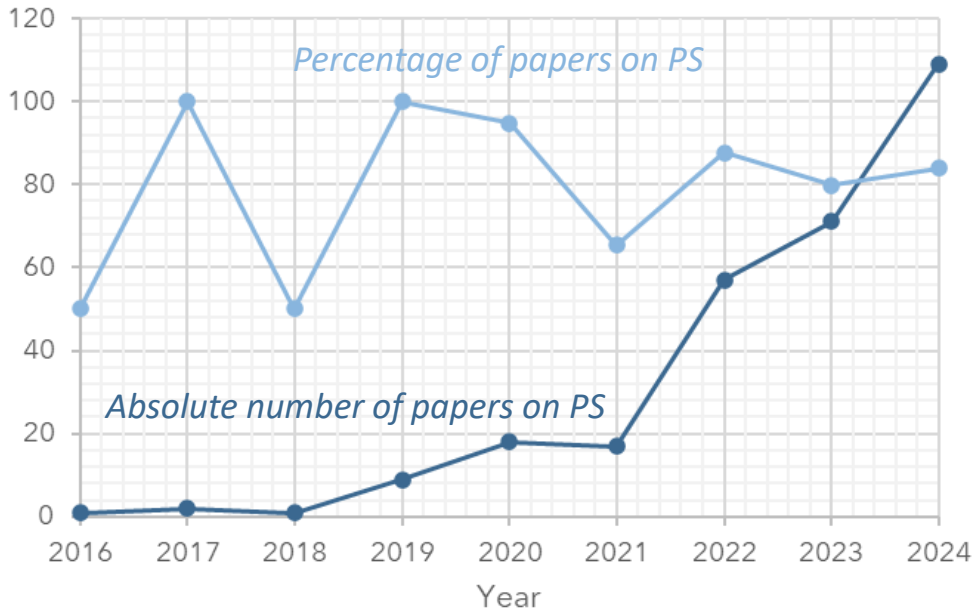
...but so far, no diversity in assessments

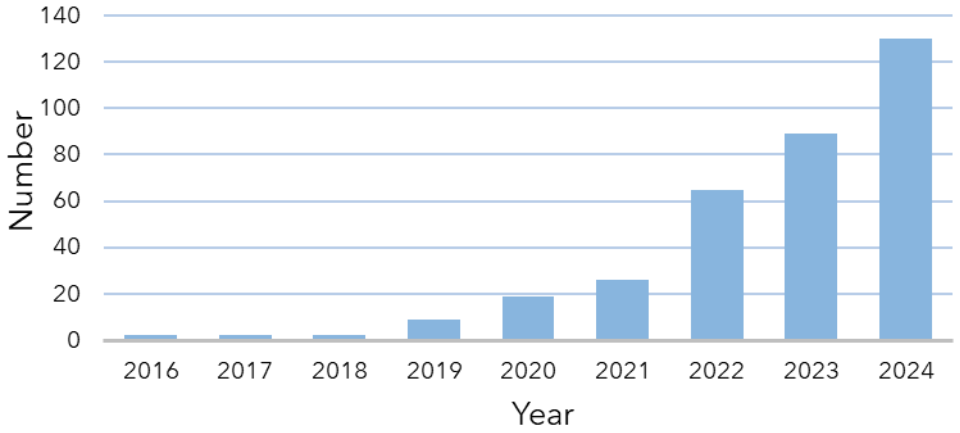
Plastic waste distribution (2015)[1]

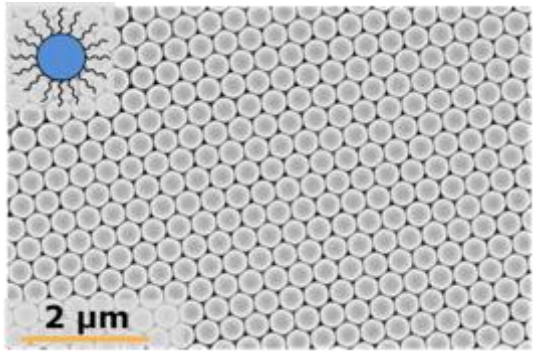


"Fluorescent NPs" in literature (<2025)[2]





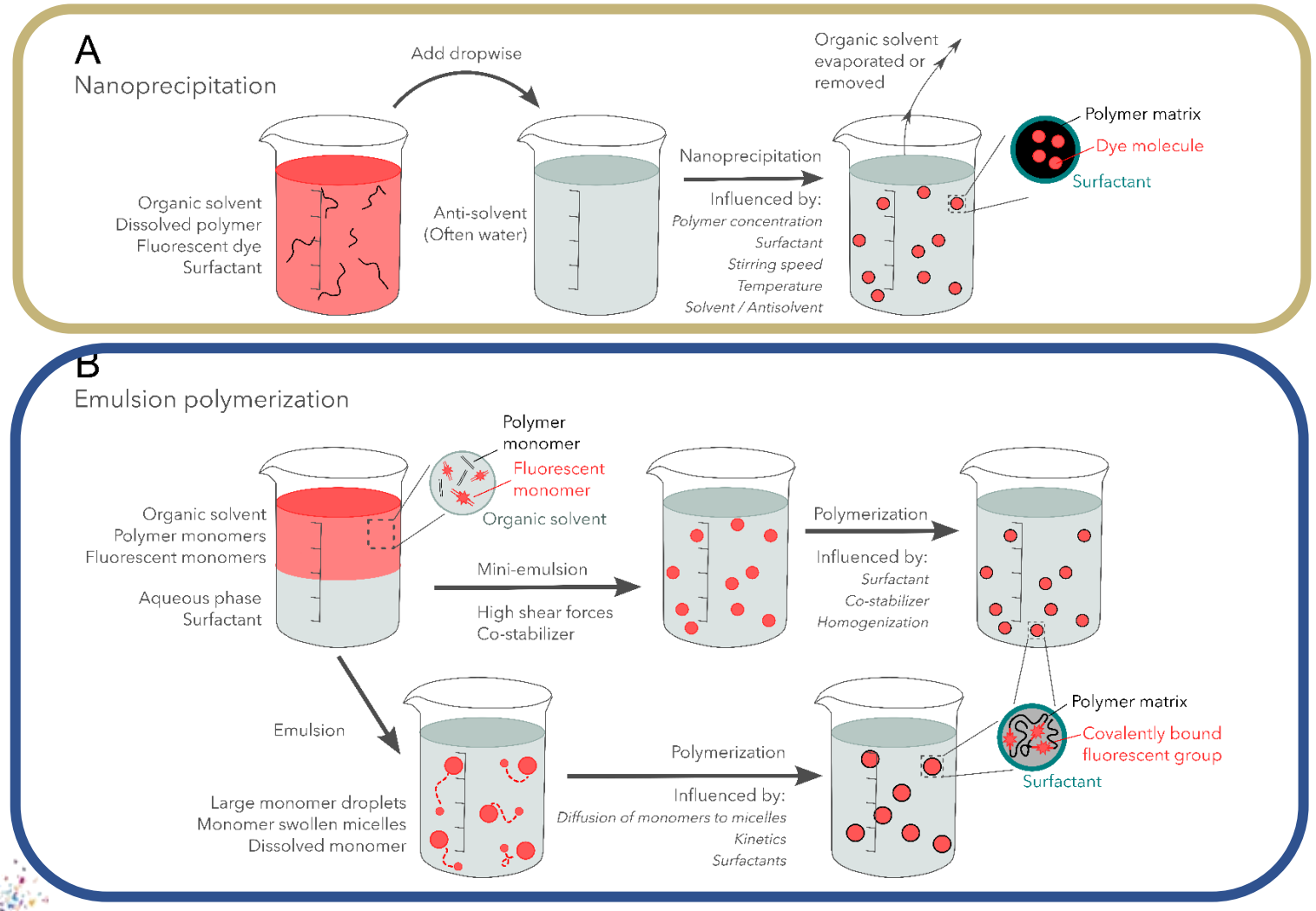




1. R. Geyer, J. R. Jambeck, K. L. Law, ***Sci. Adv.*** *2017, 3, 25–29*

2. K. van den Akker & L. D. B. Mandemaker, J.M. Dorresteijn, L. Amaral-Zettler, B. M. Weckhuysen and F. Meirer ***Micropl.&Nanopl.*** *2026, 6, 4*

Particles synthesis – Literature study



2. K. van den Akker & L. D. B. Mandemaker, J.M. Dorresteijn, L. Amaral-Zettler, B. M. Weckhuysen and F. Meirer ***Micropl.&Nanopl.*** *2026, 6, 4*

Emulsion polymerization:
Common strategy for commercial particles
Mostly PS or PMMA

Nanoprecipitation:
'Bottom-up', but actually reshaping/recycling method
Allows a variety of polymers and/or markers

Physical degradation (milling):
Yield for lower particles extremely low
Product too diverse for systematic approach

Particle synthesis – The real deal

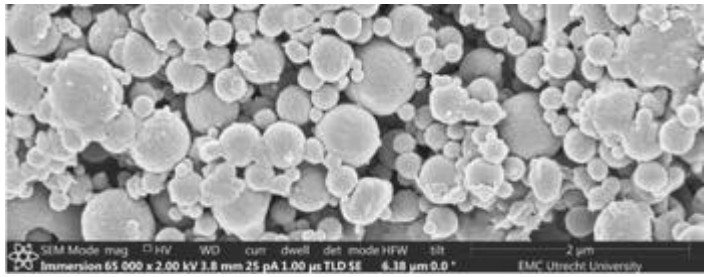
Nanoprecipitation
Five polymers
Two dyes with specific functions

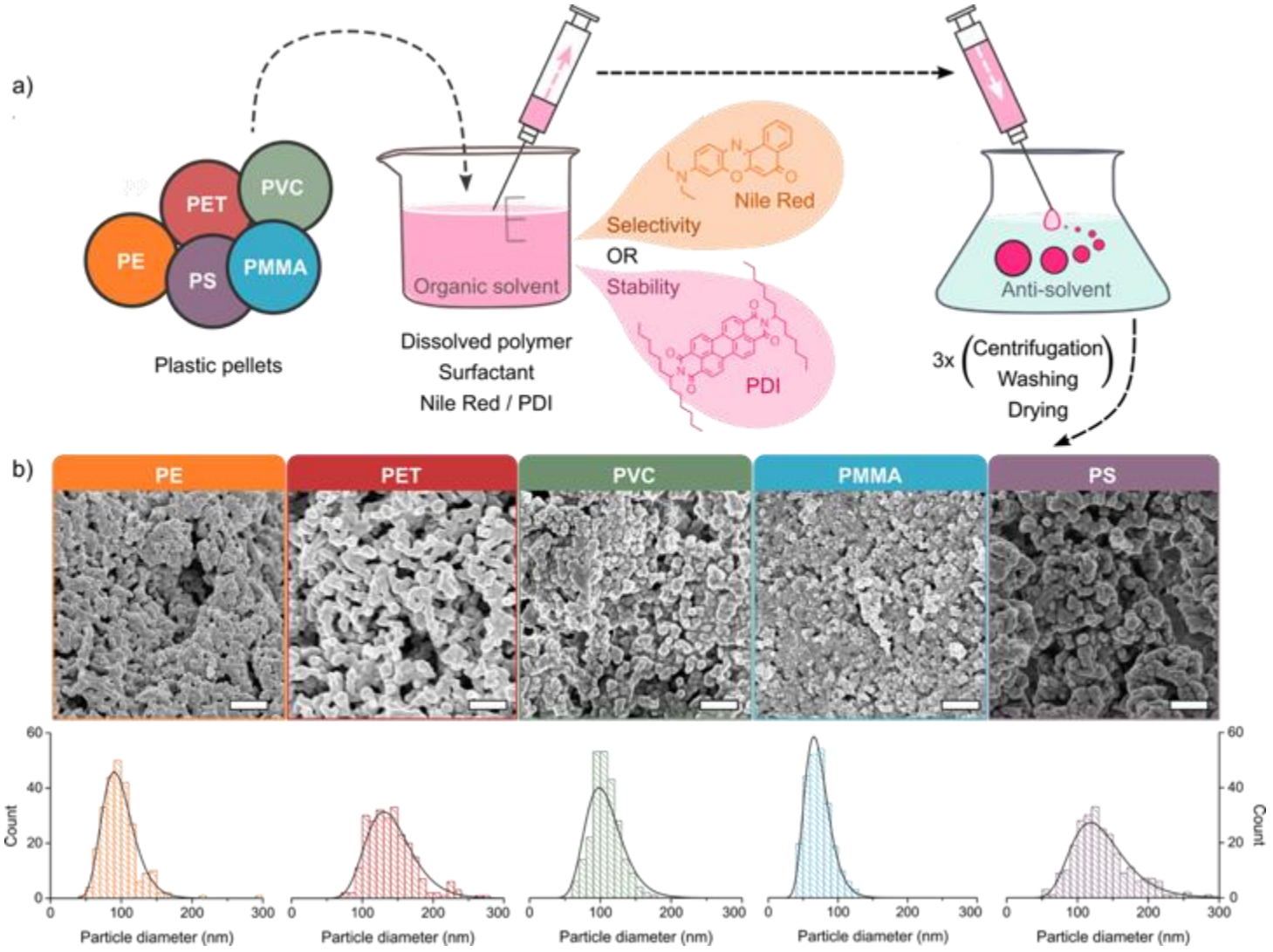
Leaching behavior monitored

Selective fluorescence

Parameter control

PA synthesized later
On demand as a particle, not a fiber

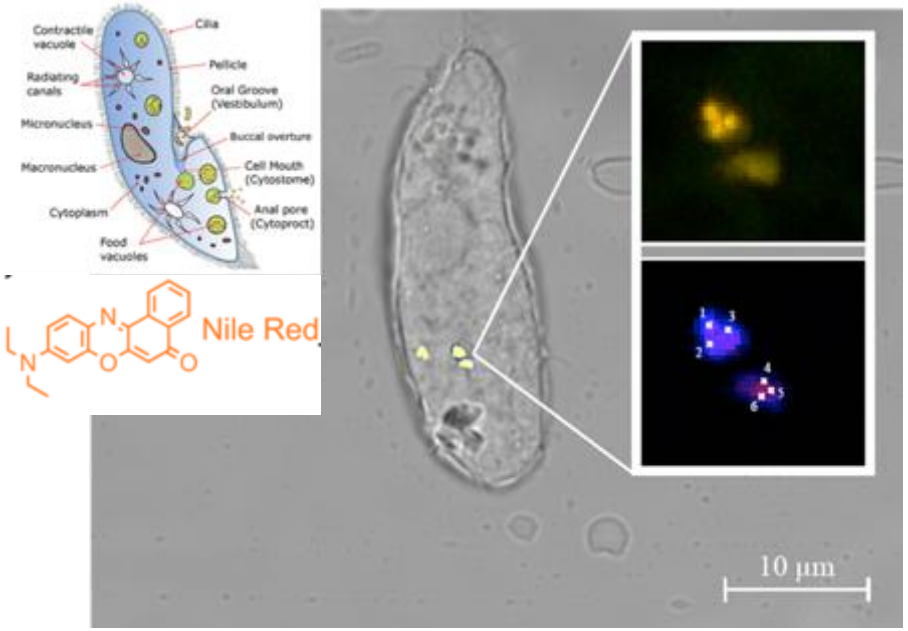


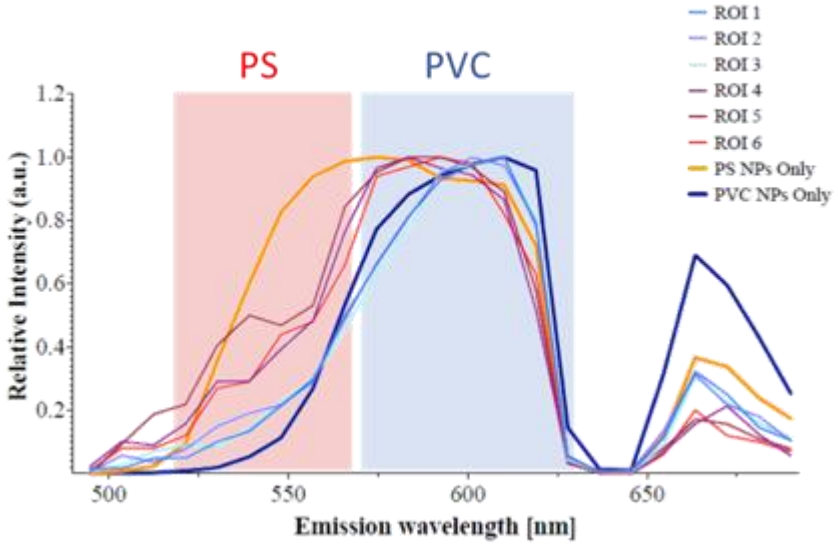


*3. L. D. B. Mandemaker, H. Spoelstra-Zwaan, L. N. Corbett, A. J. A. J. A. Duijndam, S. Song, J. M. Dorresteijn, E. R. Zettler, H. Dusza, R. Vermeulen, L. A. Amaral-Zettler, J. Legler, B. M. Weckhuysen, and F. Meirer - **in preparation***

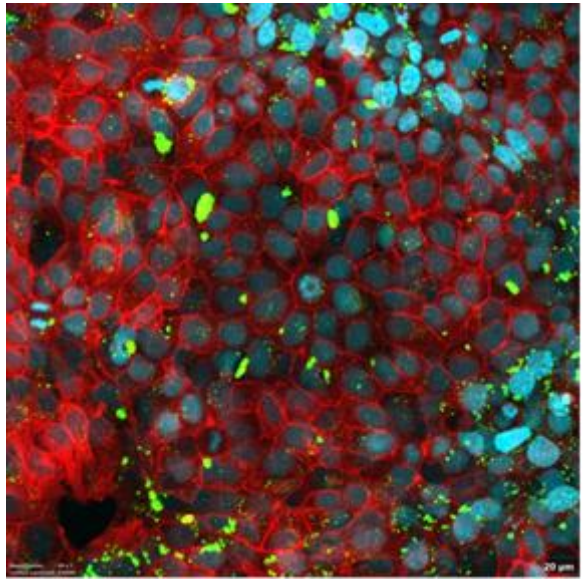
Fluorescent markers – Case studies

PMMA NR + PVC NR co-exposure

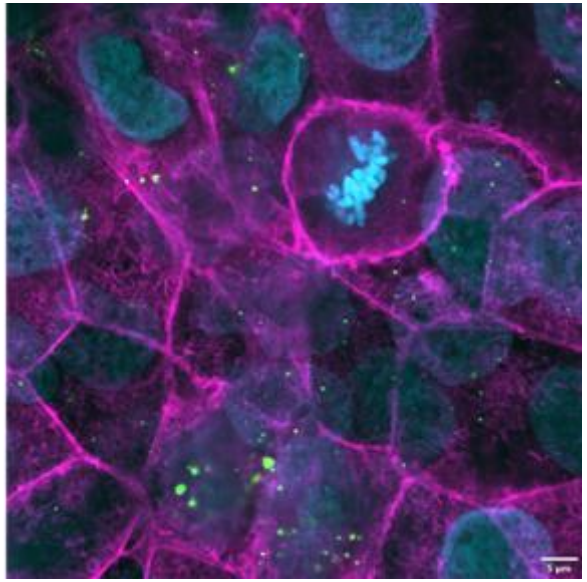




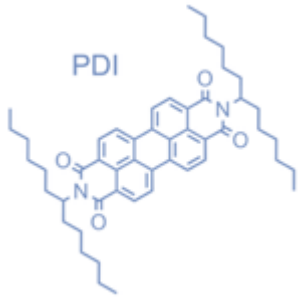
PMMA PDI 100 ug/mL



PVC PDI 100 ug/mL



Left: NR shows selective fluorescence; mapping of NP distribution
Right: PDI is highly stable and fluorescent in in-vitro assays



Emission/excitation for cell markers…

- Actin: SiR-actin kit (ex/em 652/674), pink or red
- Cell membrane: Vybrant™ (ex/em 553/570), not shown
- Nuclei: Dapi (ex/em 359/457), blue

- Credits to NIOZ partners Lia Corbett, Erik Zettler and Linda Amaral-Zettler for ciliate work
- Credits to Hanna Dusza (IRAS, UU) for BeWo cell work

Towards MNP standards

- Nanoprecipitation to have control, yet realism
  - *Scale, polymer types, size (?)*
- Robust markers to enable *in-vitro/in-vivo* studies
  - *Toxicity, uptake, translocation, etc.*
- Accessible methodology to understand what influences MNP hazards