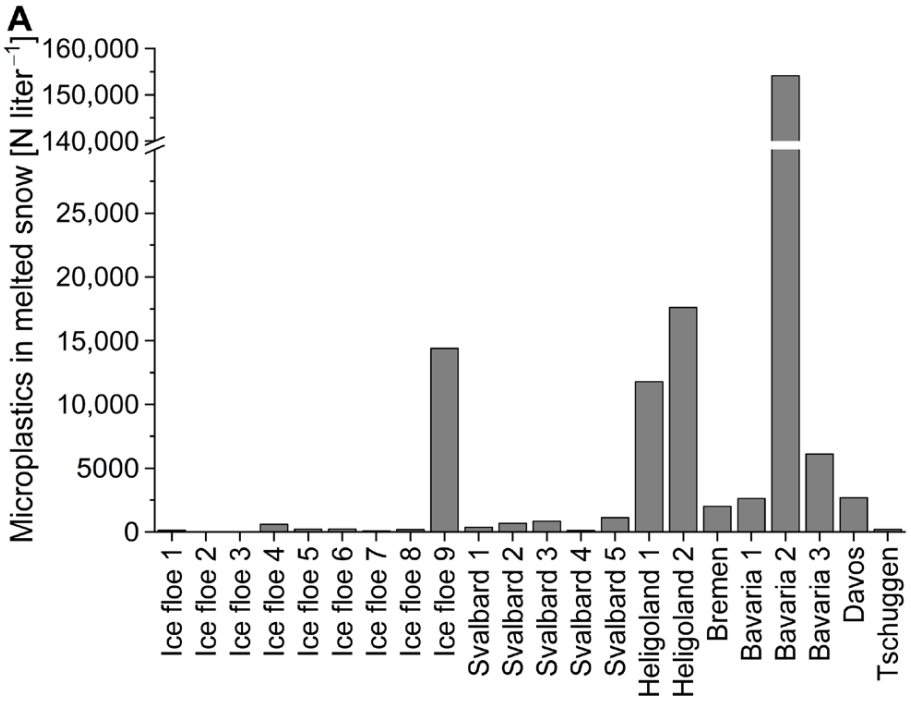
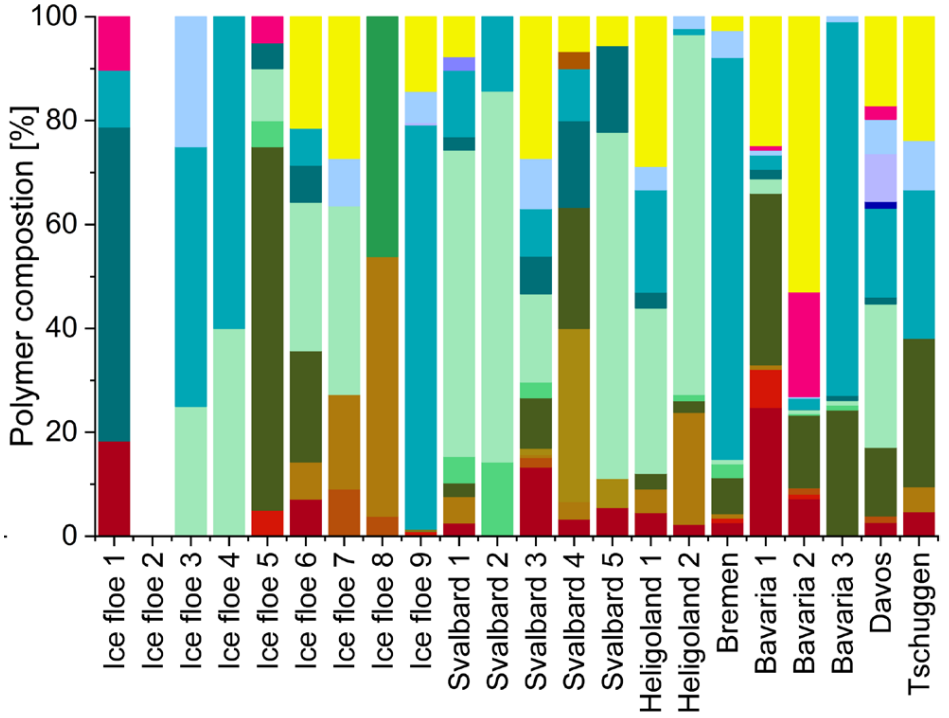
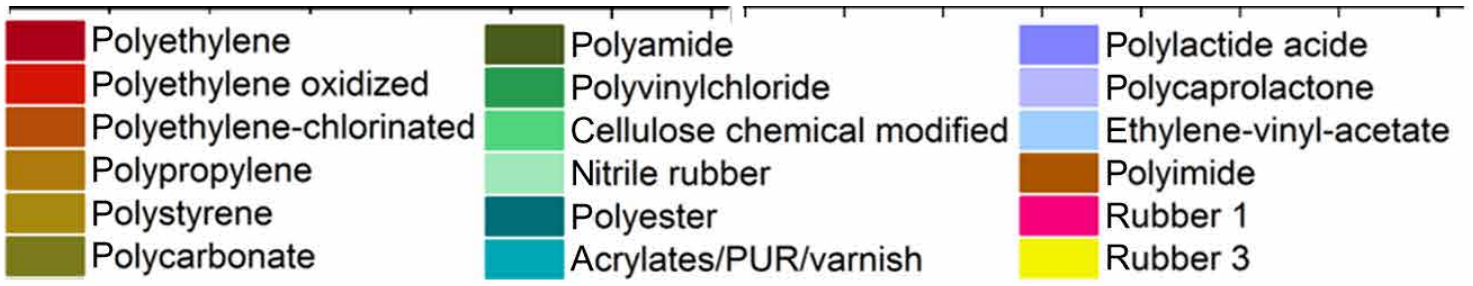
Imagine uncontaminated Artic snow…

…full of microplastics!







Human consumption of microplastics

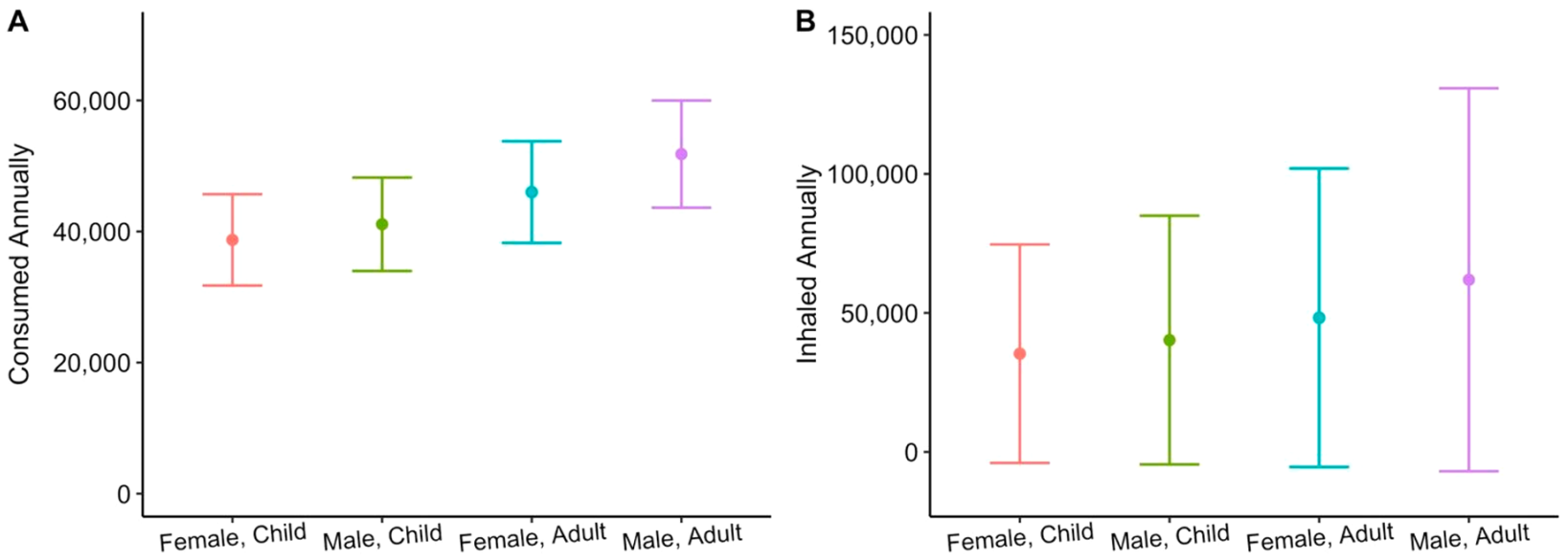


Figure 1. Total microplastic particle (MP) intake for female and male, children and adults from (A) annual consumption of commonly consumed items and (B) annual inhalation via respiration. Points and error bars represent the summation (total) and average standard deviation of all microplastics consumed.

Table 1. Daily and Annual Consumption and Inhalation of Microplastic Particles for Female and Male, Children and Adults[a]

	Daily		Annual		Total	
	Consumed	Inhaled	Consumed	Inhaled	Daily	Annually
Male Children	113	110	41106 ± 7124	40225 ± 44730	223	81331
Male Adults	142	170	51814 ± 8172	61928 ± 68865	312	121664
Female Children	106	97	38722 ± 6977	35338 ± 39296	203	74060
Female Adults	126	132	46013 ± 7755	48270 ± 53676	258	98305

[a]Points and error bars represent the summation (total) and average standard deviation of all microplastics consumed.

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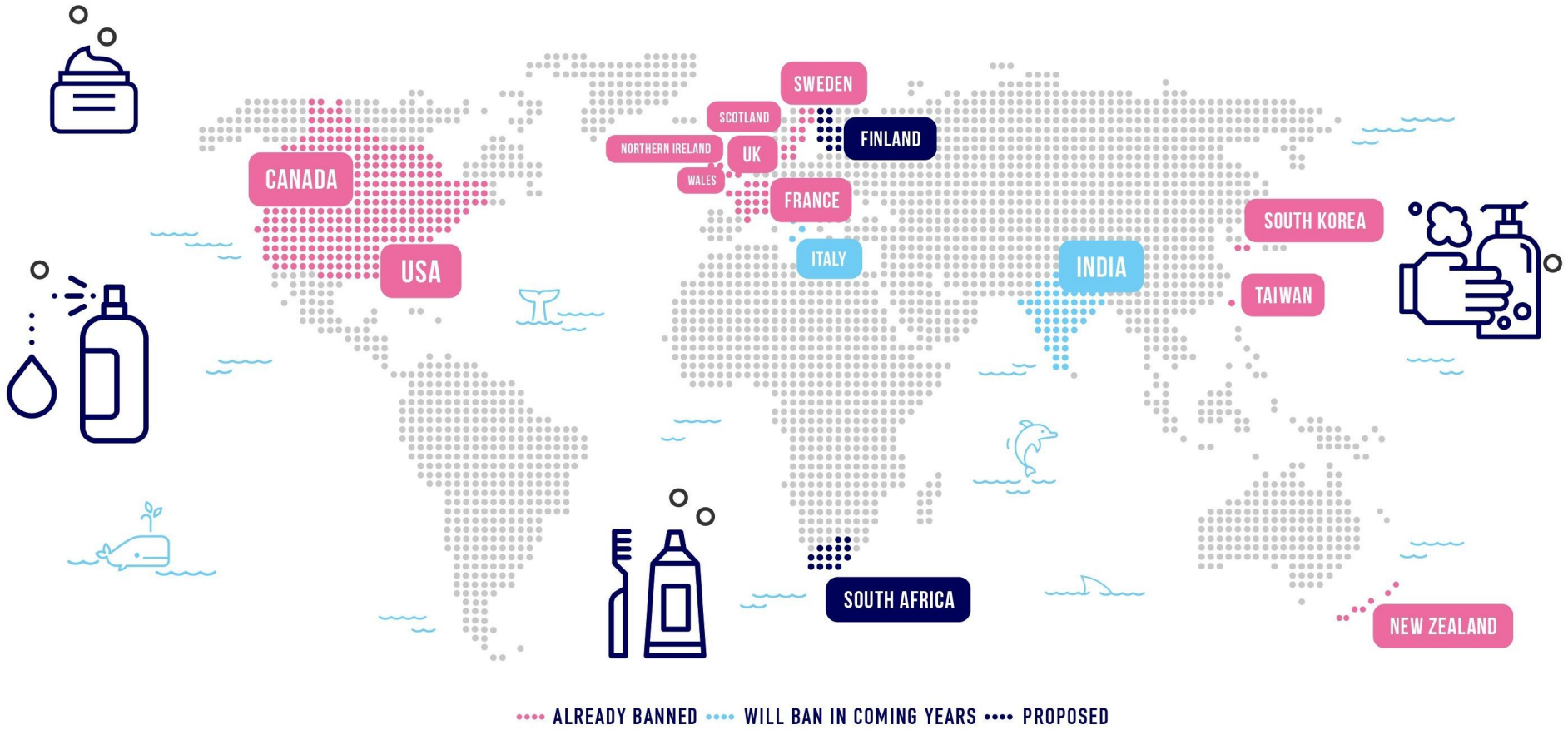
More than **250,000 tons** of microplastics enter the oceans every year

=

12 billion plastic bottles

Bans on plastic microbeads in *rinse-off* products

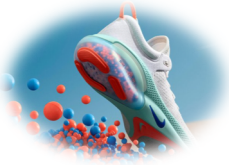


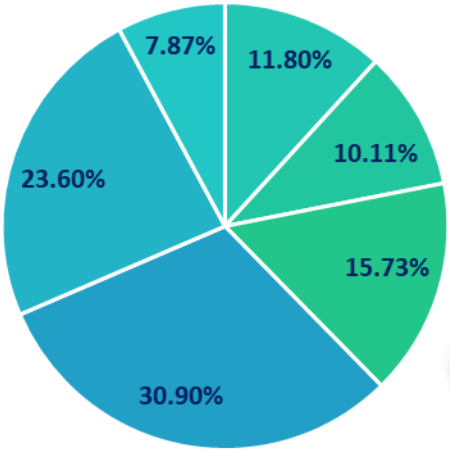
Problem Solved?

Global plastic microbeads market

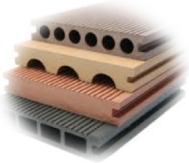
Medical £0.35B

Others £0.53B





Paint & coatings £0.45B



Fillers in composites £1.06B

Cosmetics and personal care £0.71B

Life science and biotechnology £1.39B

Global microbeads market: £4.49 billion in 2019

source: markets & markets 2019

ECHA proposes to ban ALL microplastics

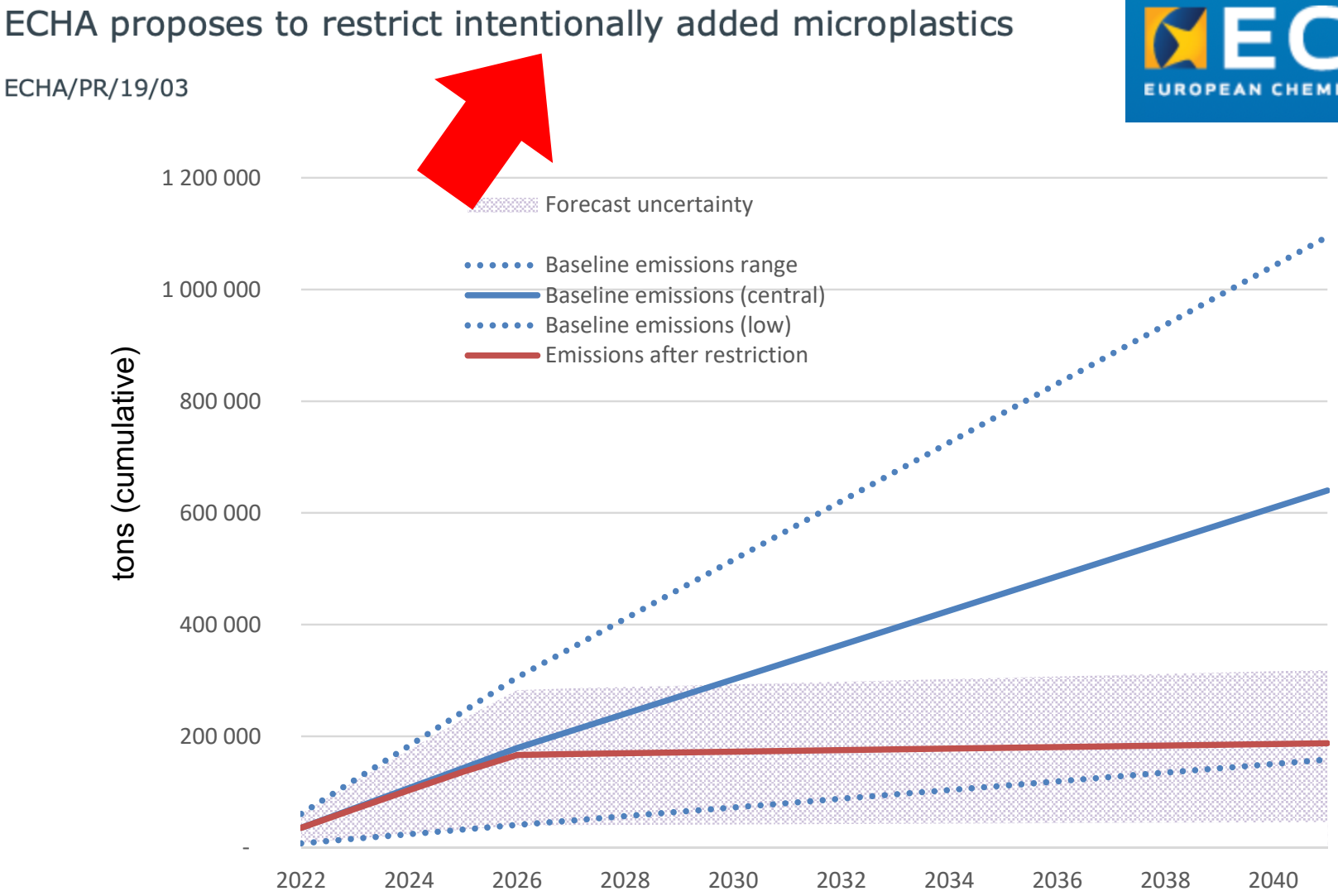
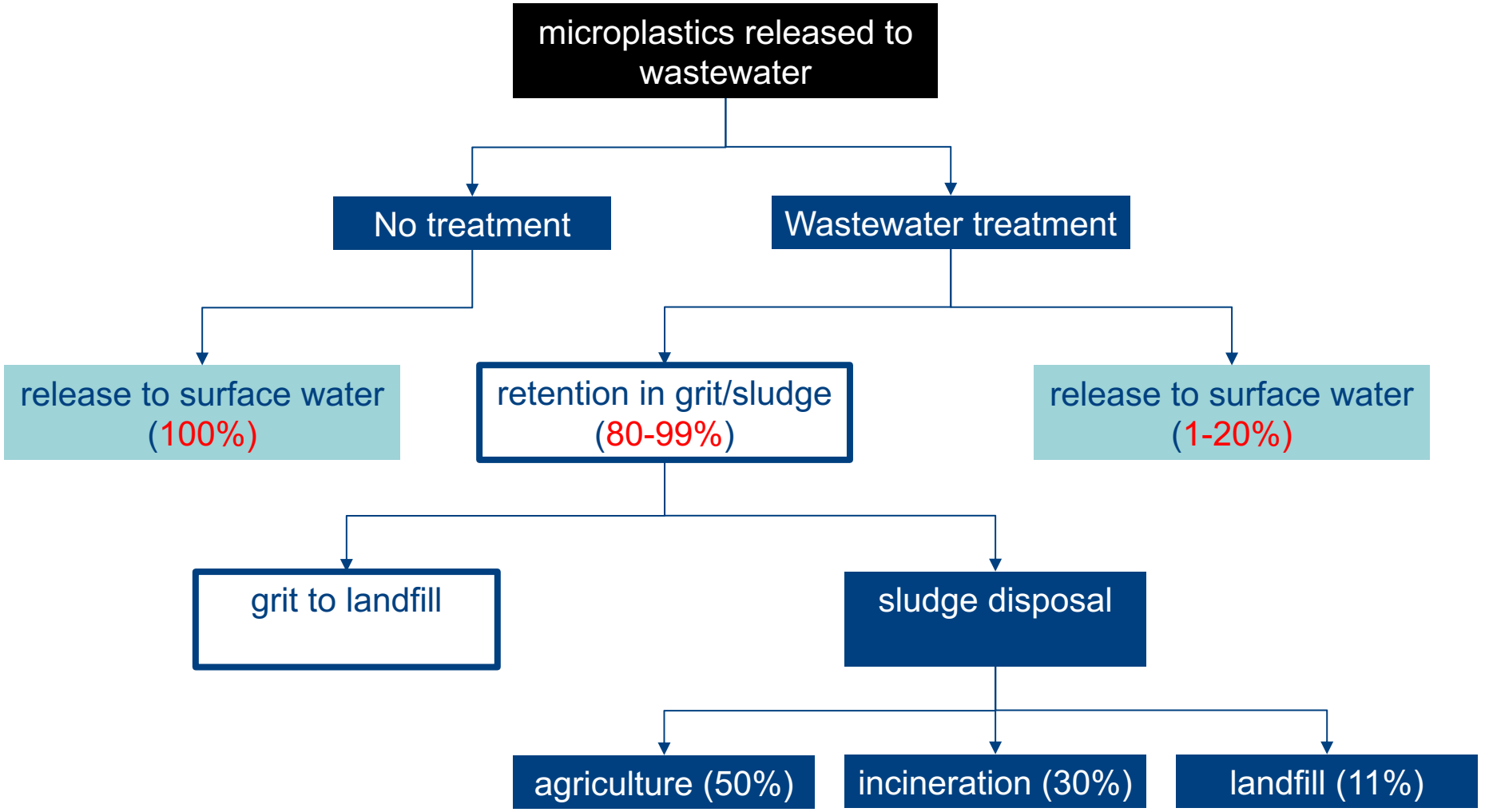


Figure 12 Effect of restriction over the period of analysis

https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e18244cd73

Plastic microbeads fate (adapted from ECHA)



Overall release from wastewater treatment: 50% (43% to soil, 7% to surface water), not including leaching from landfill and release to air.

Replacing *intentionally* added microplastics

Unlike plastic bottles, microbeads cannot be recycled nor cleaned up from the ocean or soil – they have to be removed at the source…

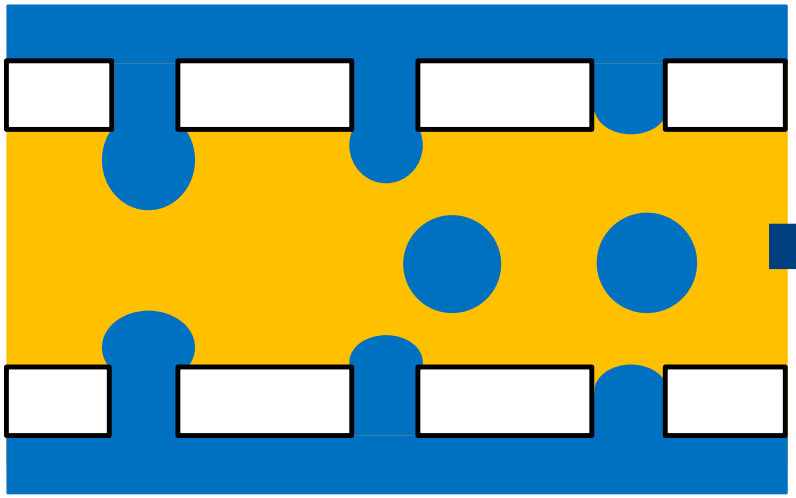
Replacing *intentionally* added microplastics

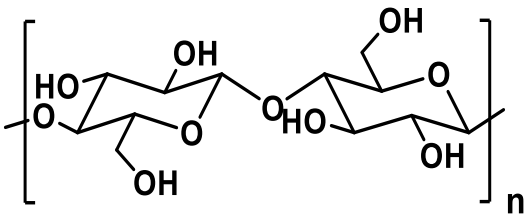
But plastic microbeads serve useful functions in a wide range of products which consumers and industry do not want do without

Our Solution: Replace plastic microbeads with biodegradable cellulose microbeads with comparable properties (and cost).

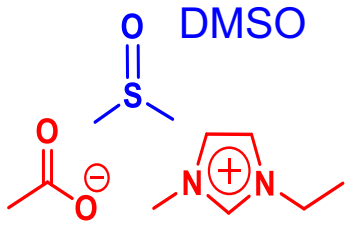
Membrane emulsification and phase inversion

Dispersed phase:
IL/DMSO/Cellulose



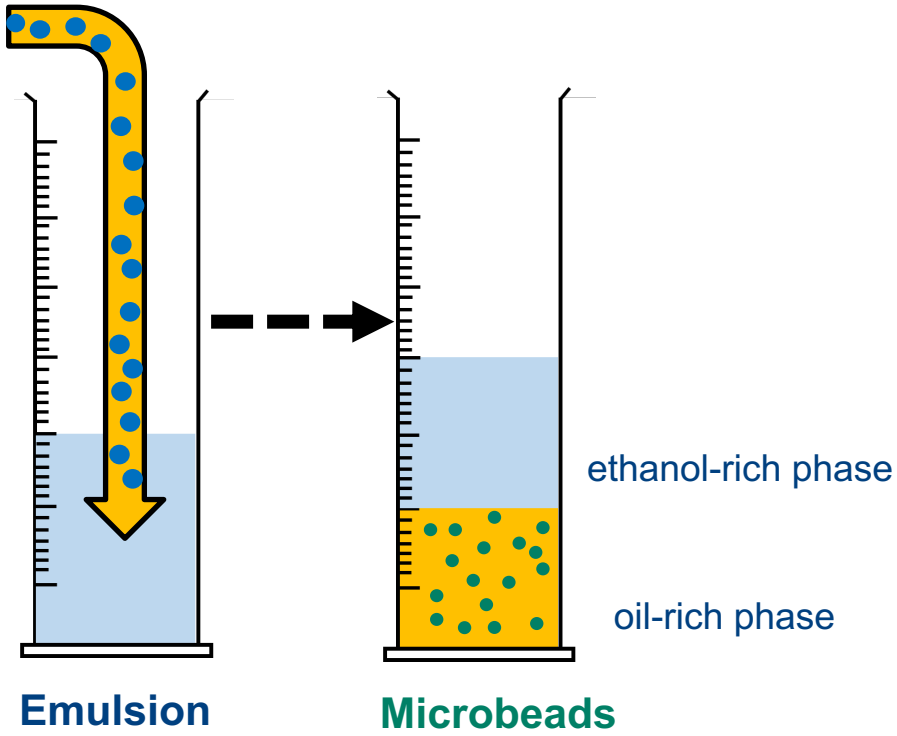


cellulose



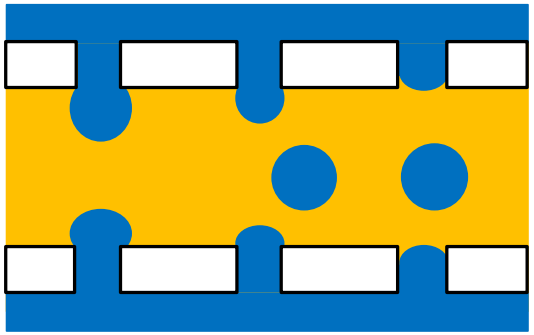
ionic liquid

Continuous phase:
Sunflower oil + Span 80

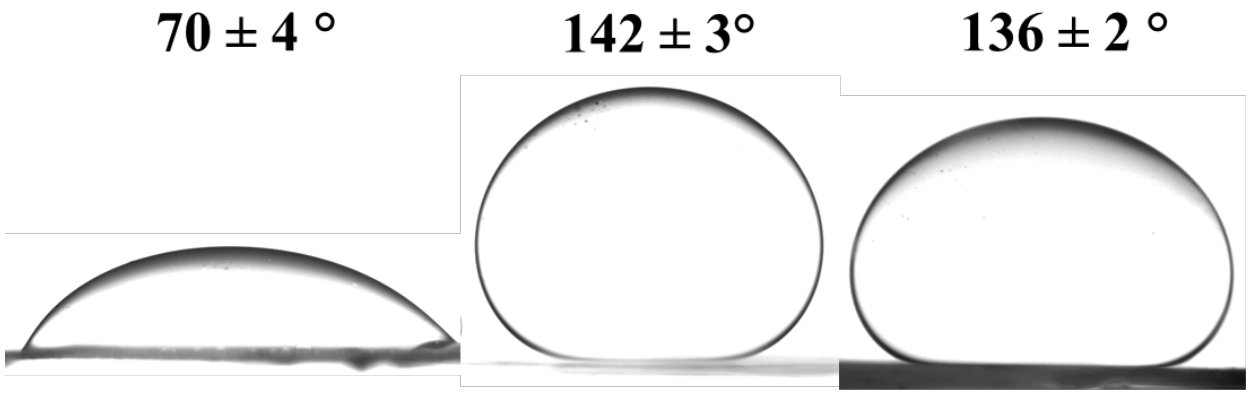


Coombs Obrien, J. *et al*. *ACS Sust. Chem & Eng.* **2017,** *5* (7), 5931-5939.

Hydrophobized SPG 10 μm membrane

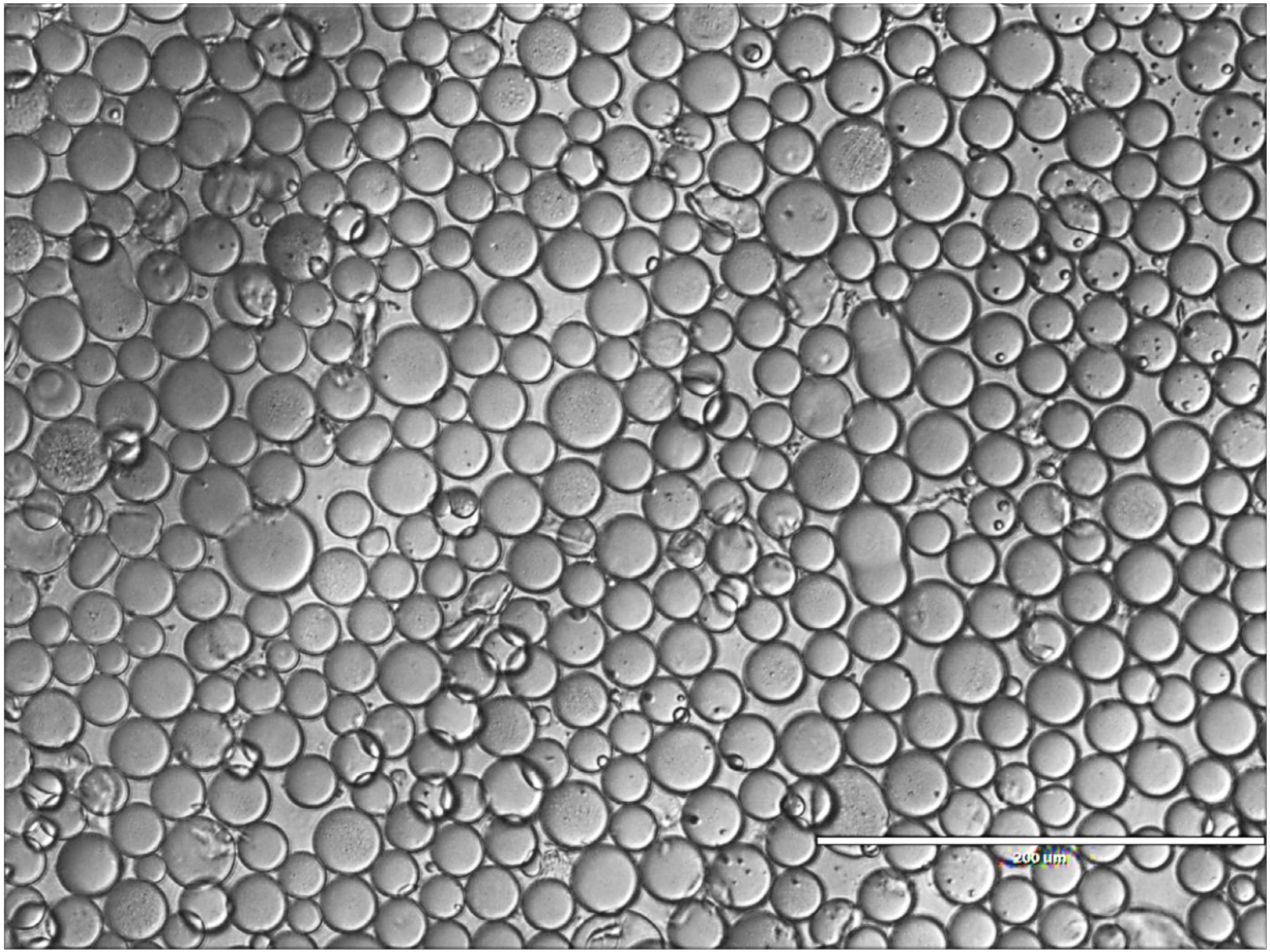


The hydrophilic SPG membranes were hydrophobized using $C_{18}H_{39}SiCl_3$

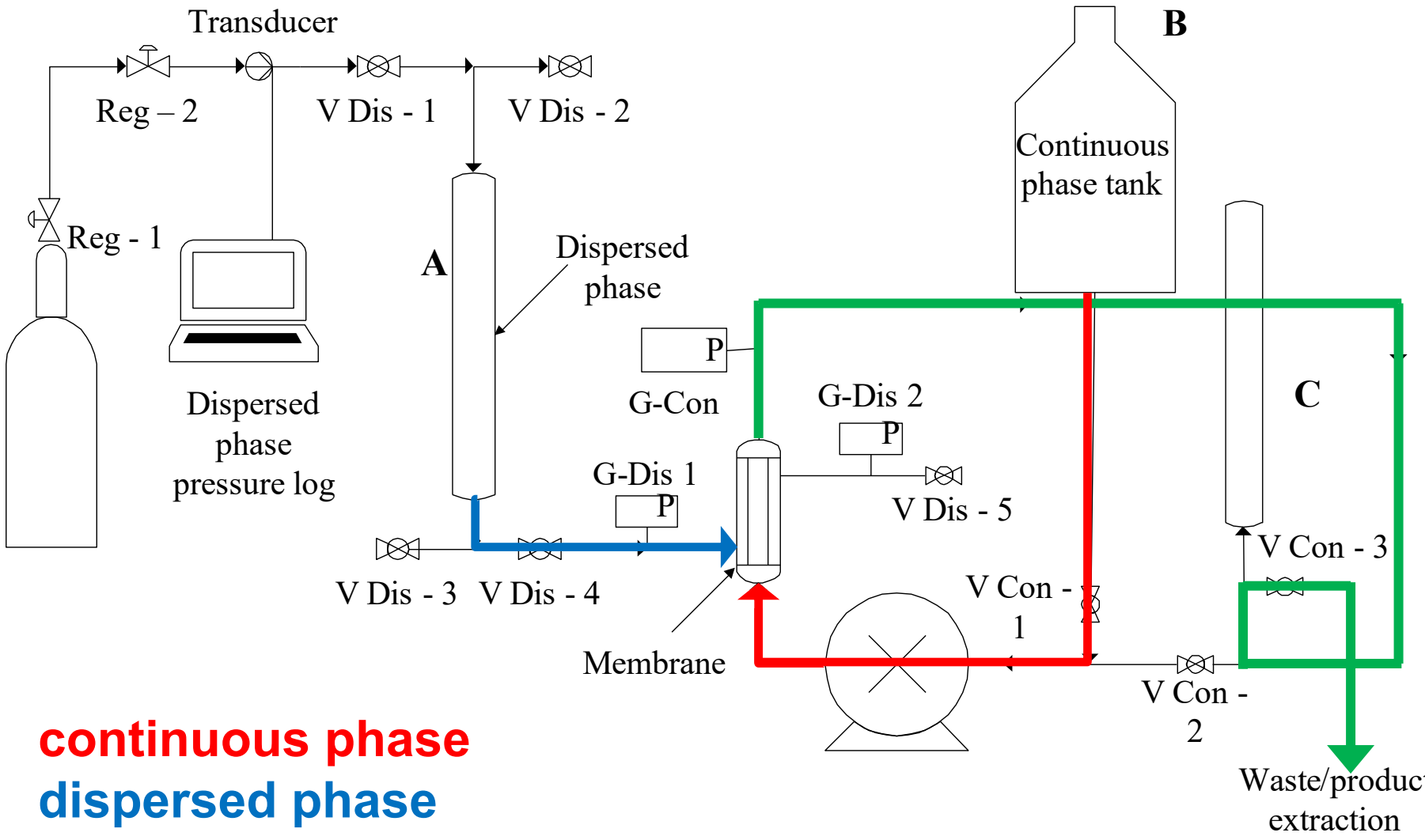


	A	B	C
Hydrophobised glass	×	✓	✓
Surfactant (2 wt% Span 80)	✓	×	✓

Cellulose emulsion before phase inversion



Membrane Emulsification Apparatus 1/2

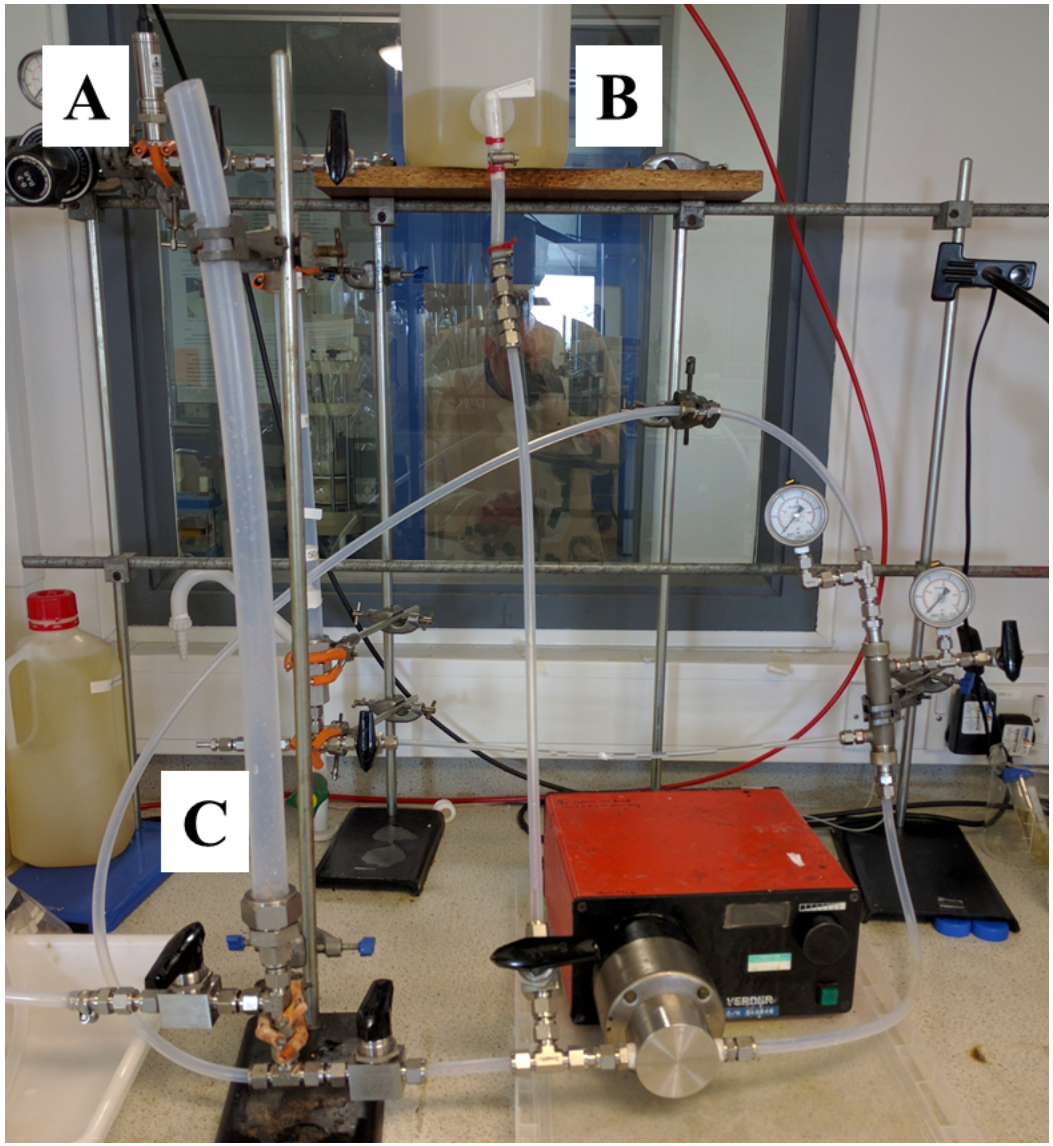


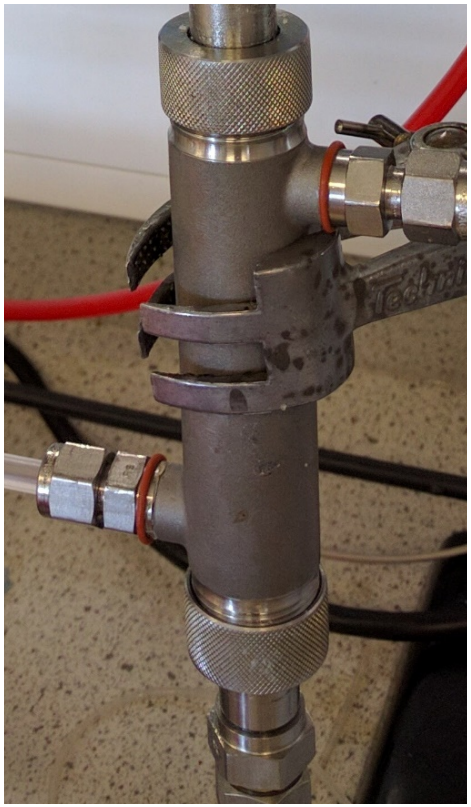
continuous phase

dispersed phase

emulsion

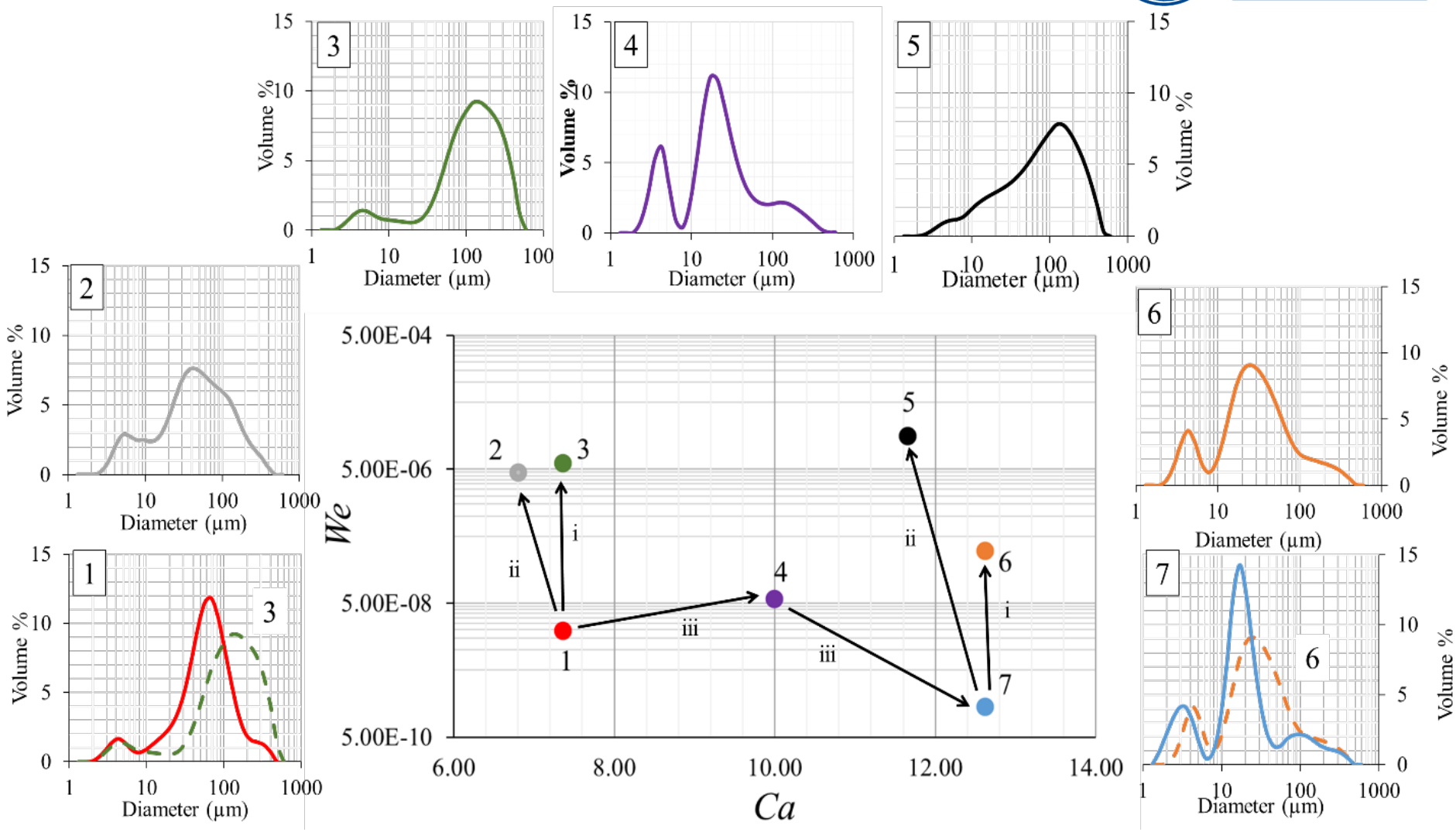
Membrane Emulsification Apparatus 2/2





SPG membrane:
10 μm av. pore diameter
12.5 cm long, 1cm dia.

Emulsification Process control

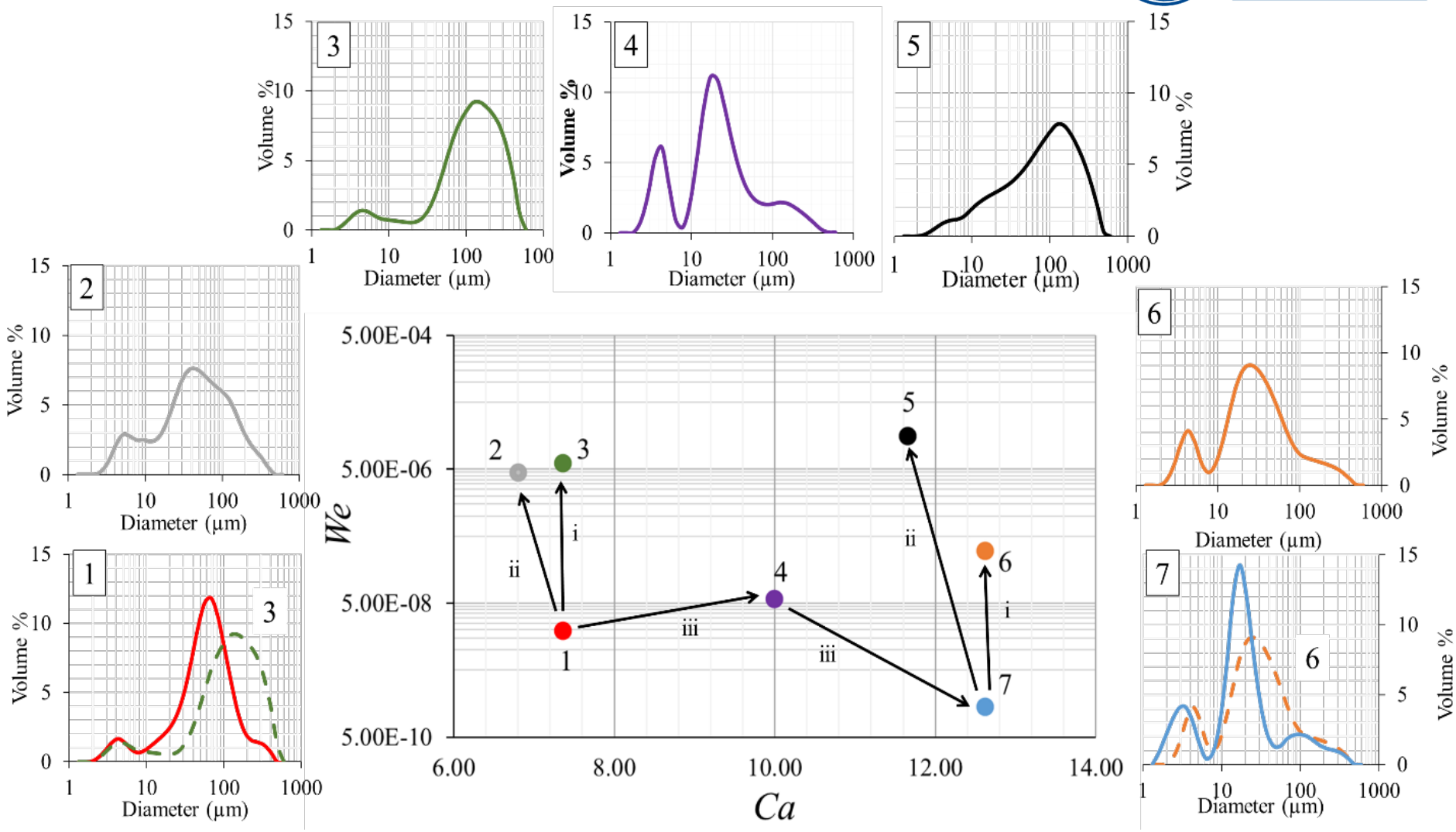


$$Ca = \frac{\mu_{cp} v_{cp}}{\gamma}$$

$$We = \frac{\rho_{dp} v_0^2 D_0}{\gamma}$$

Ca and *We* represent the ratio of viscous/inertial to interfacial tension forces in the emulsion formation process

Emulsification Process control

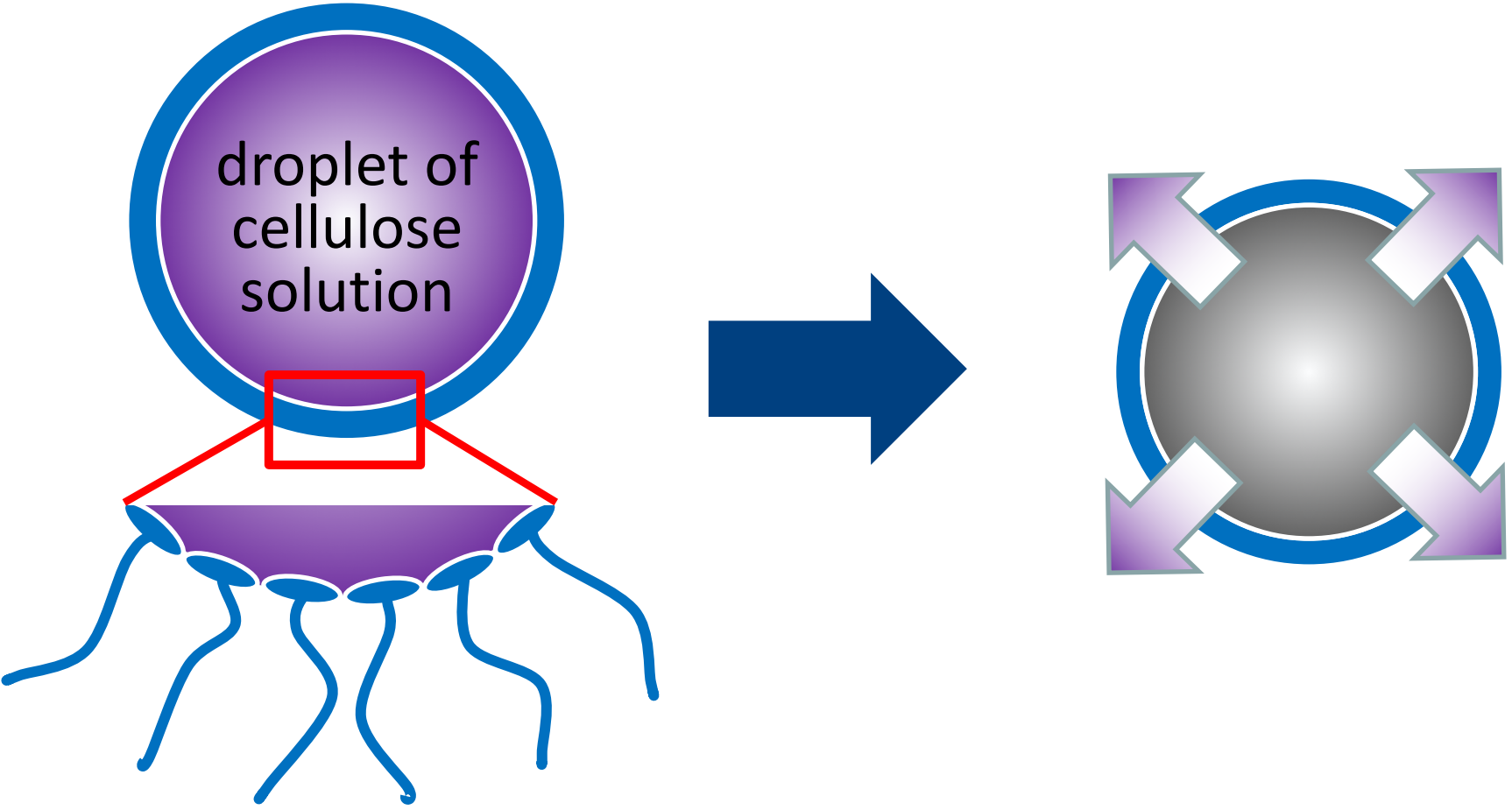


(i) increase in TMP

(ii) reduction of cellulose concentration

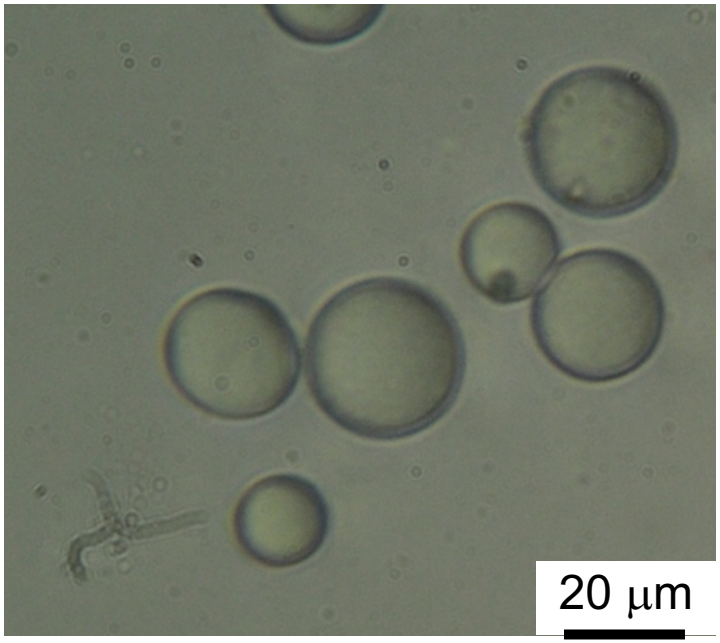
(iii) increased continuous phase flow rate

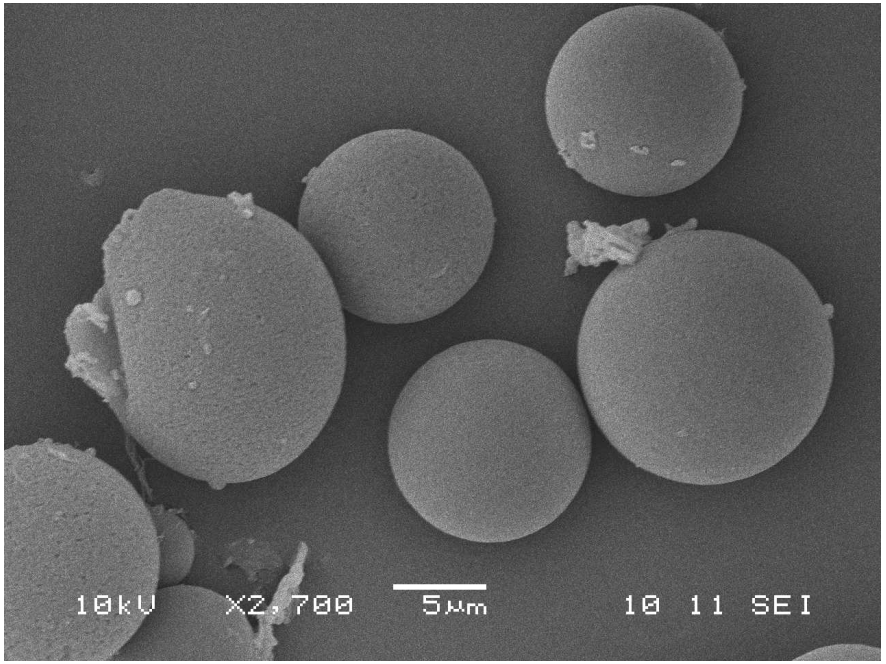
Phase Inversion

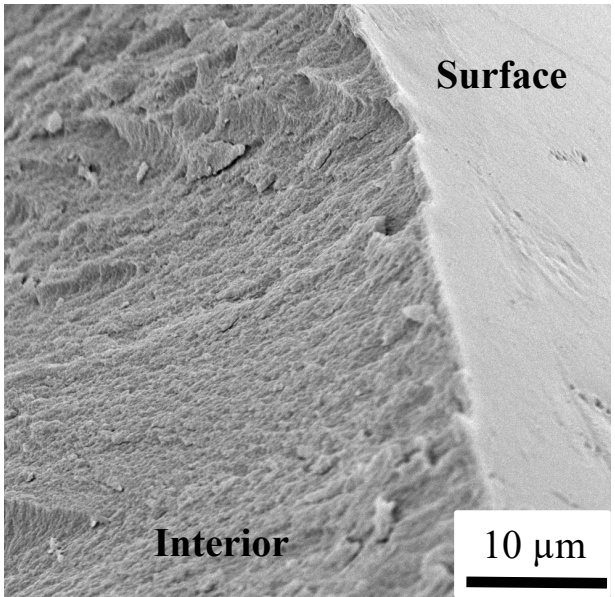


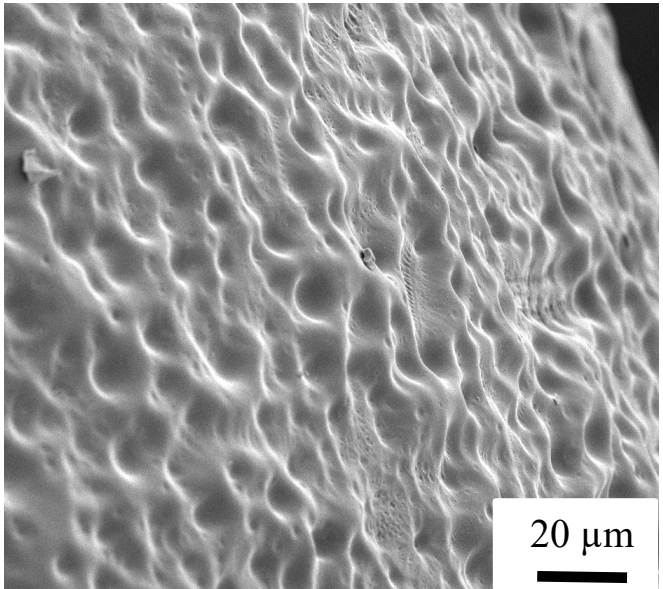
The anti-solvent (ethanol) penetrates the droplet, precipitating the cellulose particles.

Cellulose Microbeads



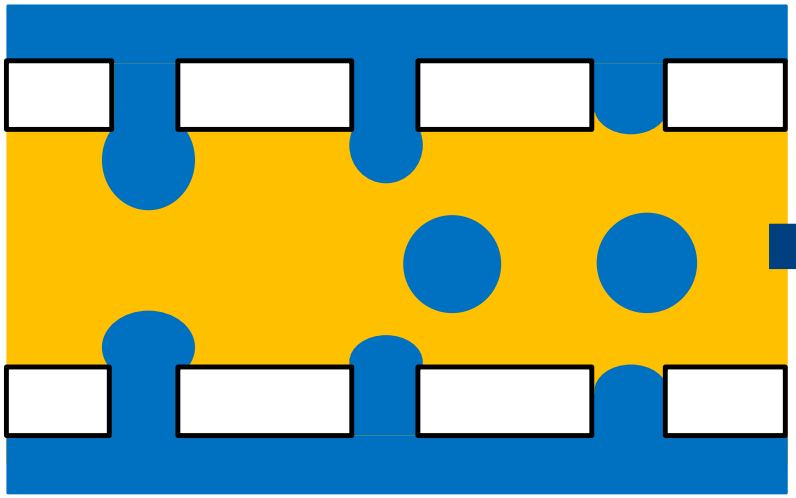


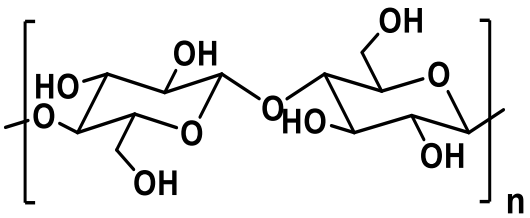




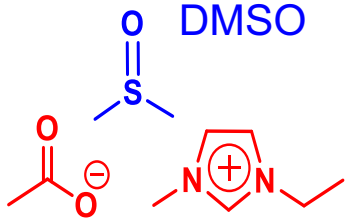
Cellulose beads chemical modification

Dispersed phase:
IL/DMSO/Cellulose

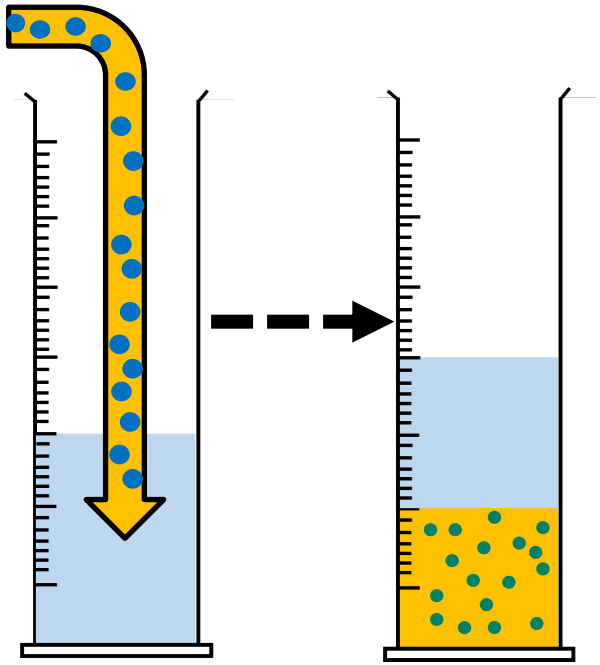




cellulose



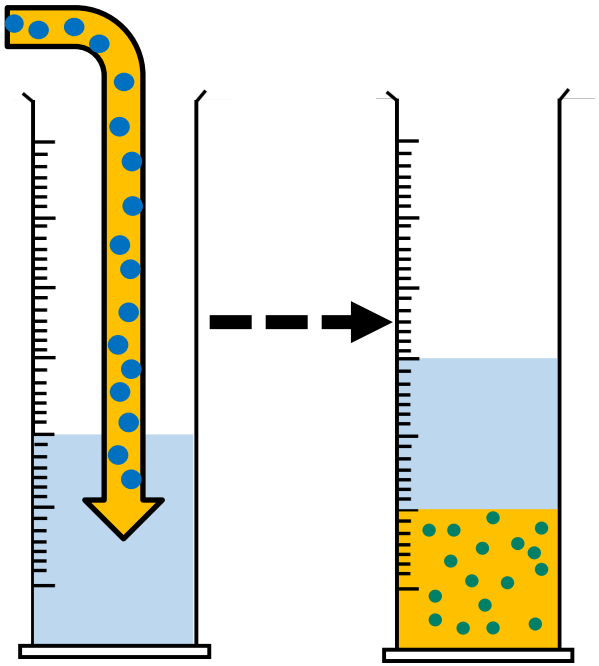
ionic liquid



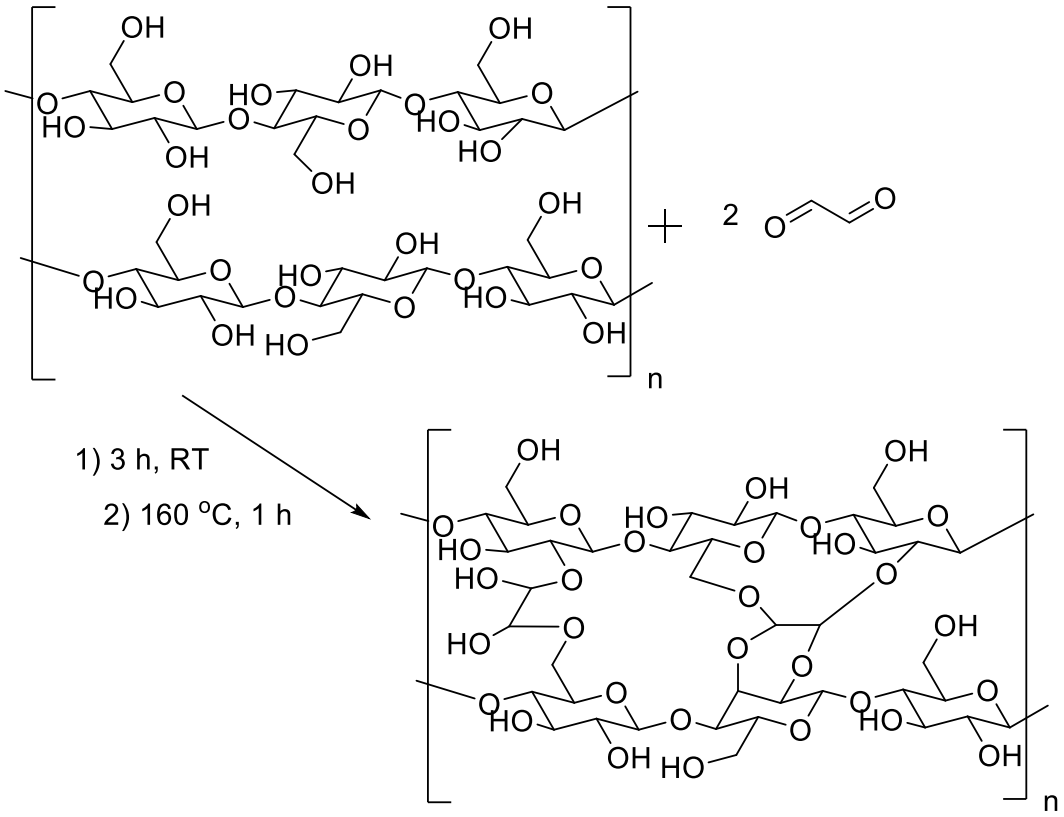
Continuous phase:
Sunflower oil + Span 80

Microbeads

Cellulose beads chemical modification



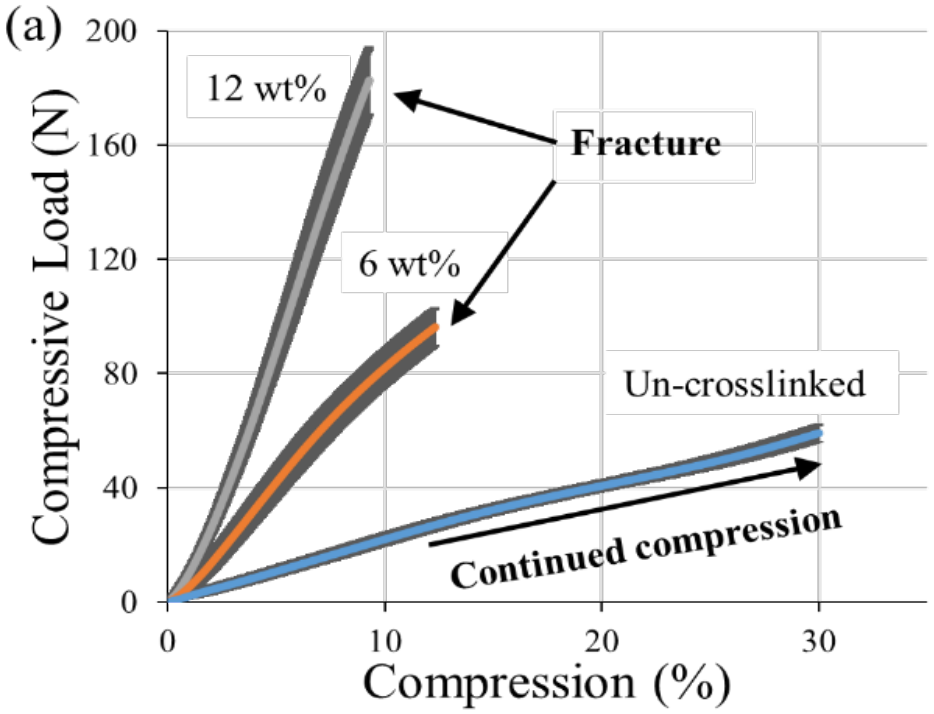
Microbeads

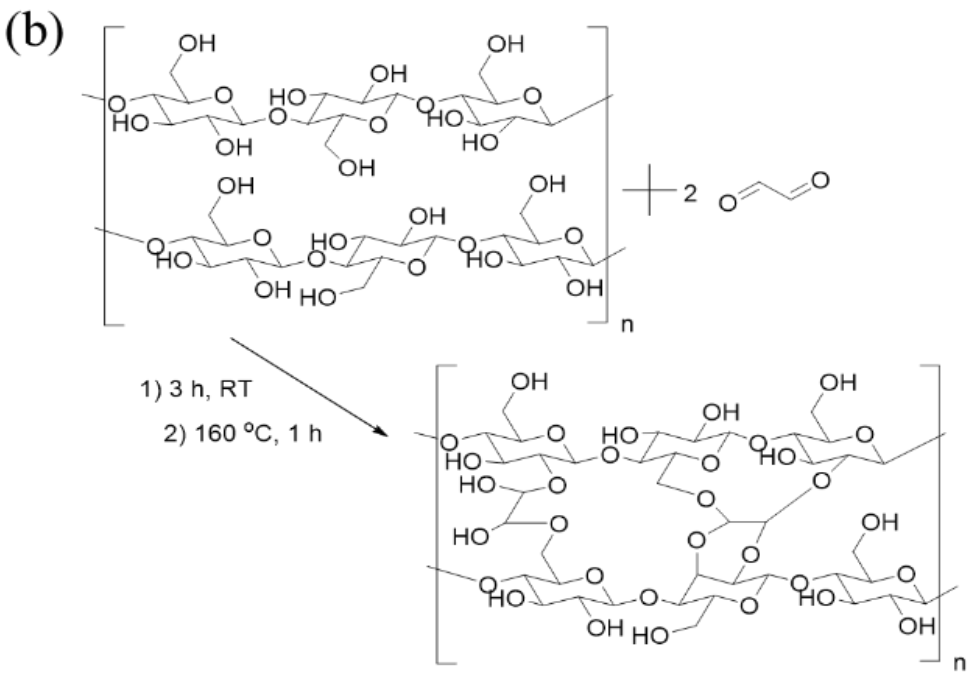


Post-fabrication crosslinking using glyoxal

Cellulose beads chemical modification

Crosslinking with glyoxal, 3h RT, followed by 1h at 160 °C

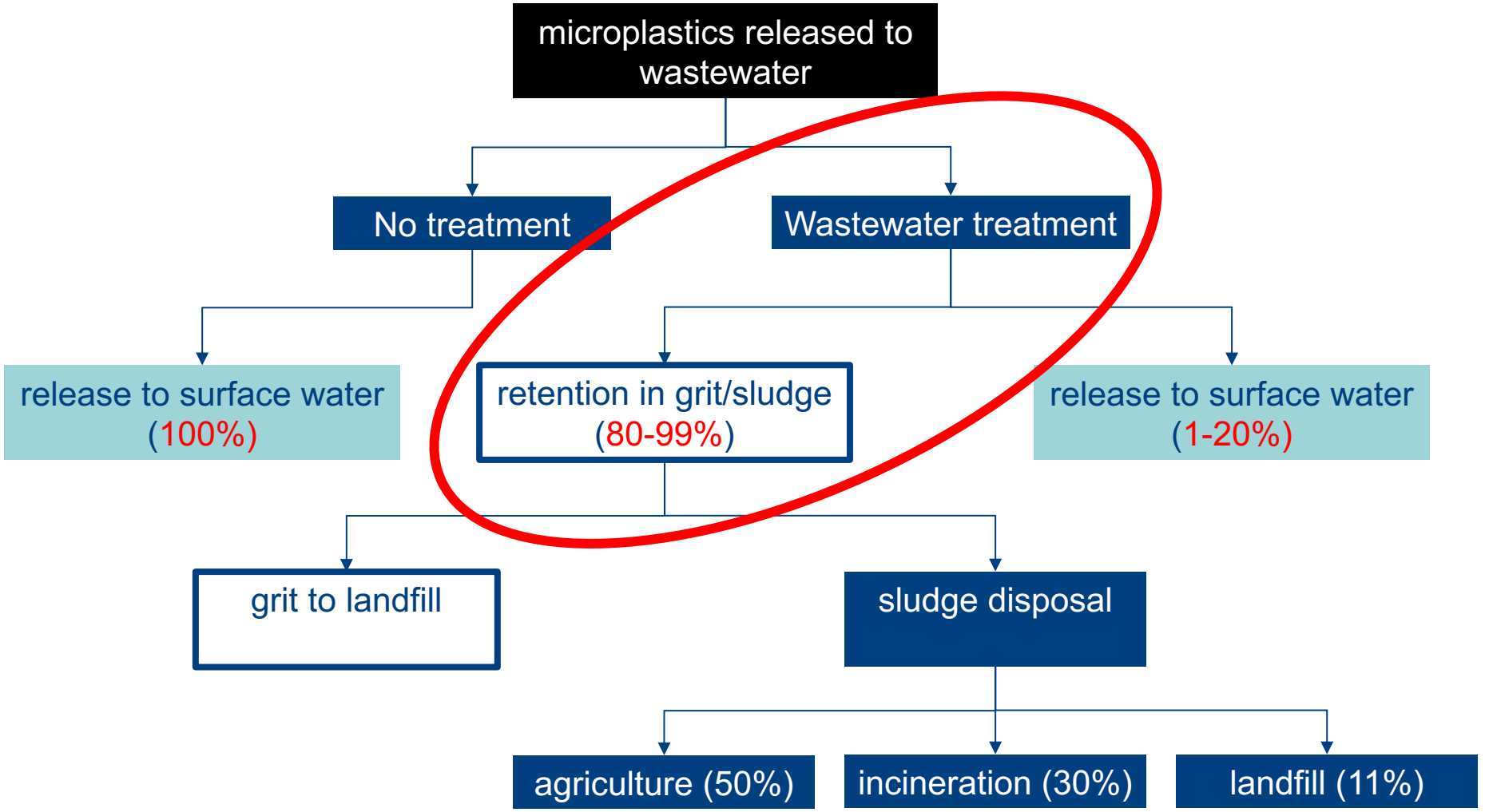




The cross-linked cellulose beads have a higher compression load with the same surface roughness and biodegradability.

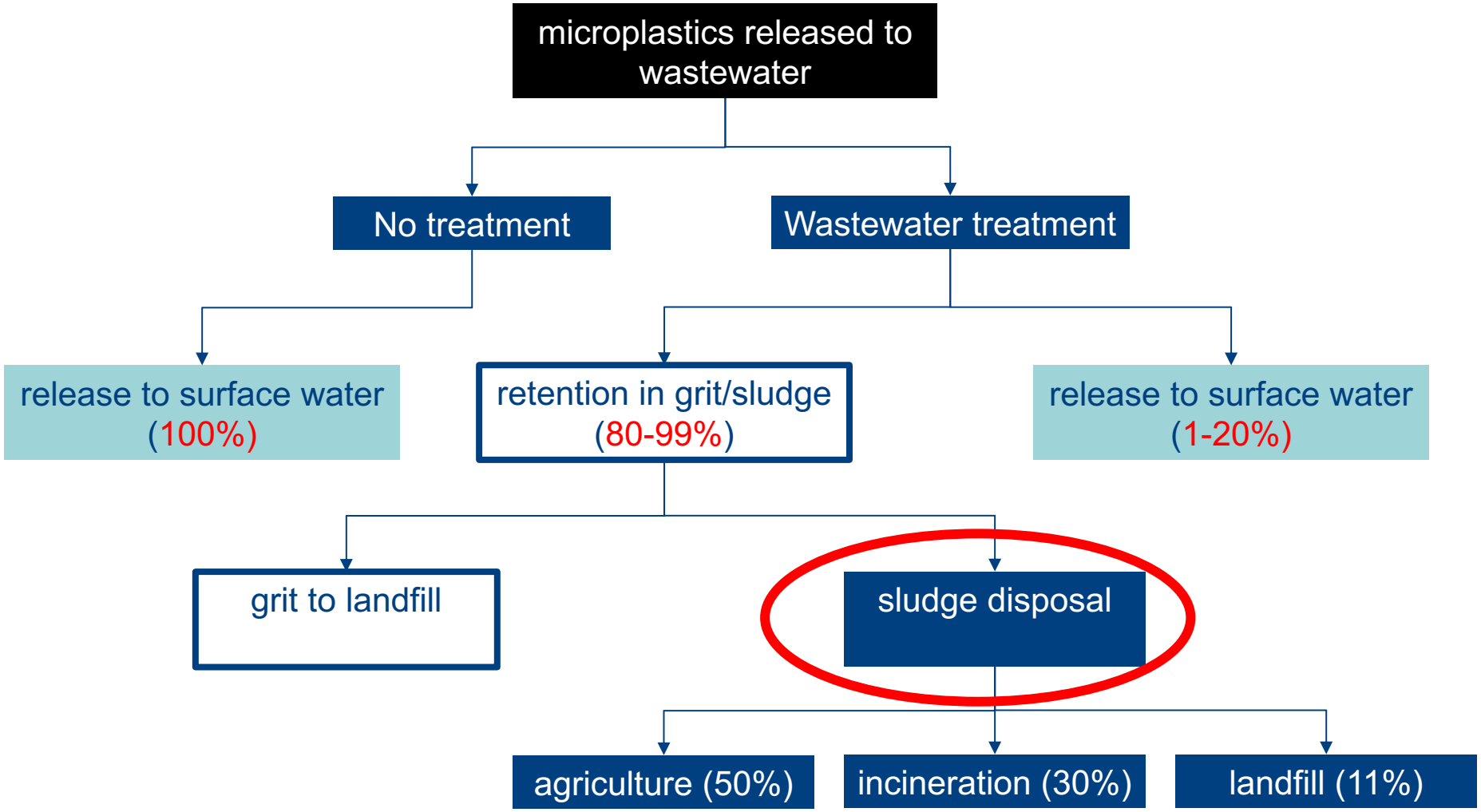
Coombs Obrien, J. *et al*. *ACS Sust. Chem & Eng.* **2017,** *5* (7), 5931-5939.

Are cellulose beads actually biodegradable?



Overall release from wastewater treatment: 50% (43% to soil, 7% to surface water), not including leaching from landfill and release to air.

Are cellulose beads actually biodegradable?



Scope: to determine and characterise the biodegradation of cellulose beads under both anaerobic and aerobic conditions.

Challenges in scaling-up the process

- **Productivity**:

Initially: 1 vol% of dispersed phase (4wt% cellulose) in continuous phase

Currently: 30 vol% of dispersed phase (8wt% cellulose) in continuous phase

this translates to 3-10 kg/h per m^2 of membrane.

- **Viscosity:**

Cellulose concentration (wt.%)	Viscosity (Pa.s) [a]	Density (g/mL)	Interfacial tension (mN/m) [b]	Contact angle (°) [c]
8	1.18 (± 0.01)	1.13 (± 0.0004)	1.57 (± 0.02)	133 (± 2)
4	0.13 (± 0.01)	1.12 (± 0.001)	1.70 (± 0.04)	136 (± 2)

[a] average across Newtonian range; [b] with sunflower oil-2 wt% Span 80; [c] on hydrophobised glass

- Solvent Recycling and Particle Recovery
- Membrane Fouling
- Long-term stability

From Research to Commercialisation

UNIVERSITY OF BATH

Innovate UK

ACS Sustainable Chemistry & Engineering

Research Article

pubs.acs.org/journal/ascecg

Continuous Production of Cellulose Microbeads via Membrane Emulsification

James Coombs OBrien,[†,‡] Laura Torrente-Murciano,[§,∥] Davide Mattia,[*,§,∥] and Janet L. Scott[*,†,∥]

BIOBEADS

2012 | 2013 | 2017 | 2018

CSCT PhD
James Coombs OBrien

BBC Sign in

NEWS

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Science & Environment

Plastic microbead ban

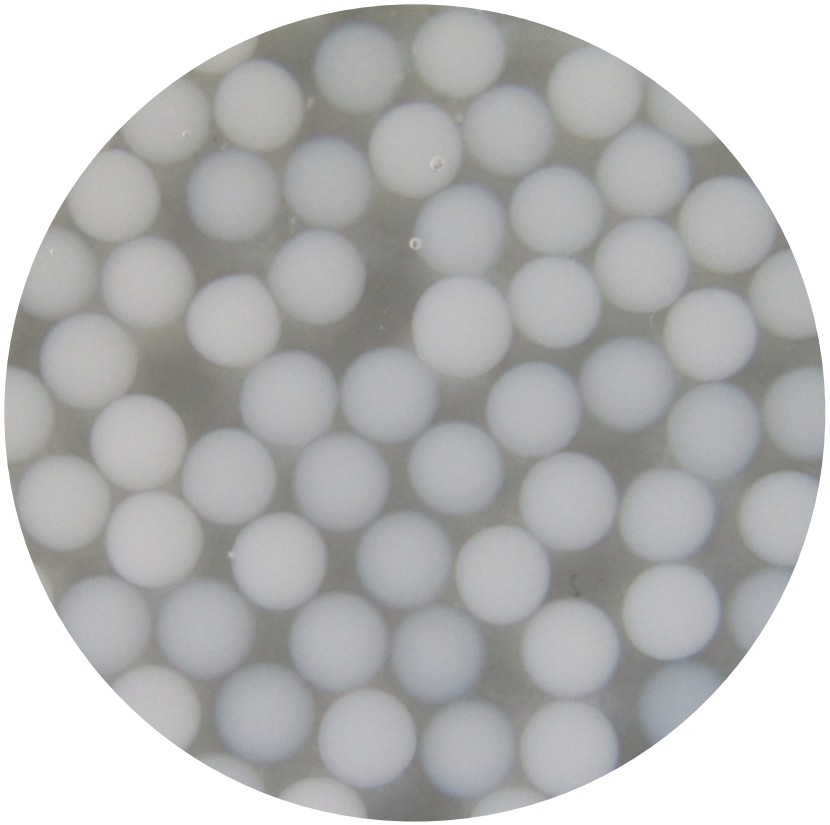
EPSRC
UoB IAA

NATURBEADS

Natural biodegradable microbeads

NATURBEADS

Natural biodegradable microbeads



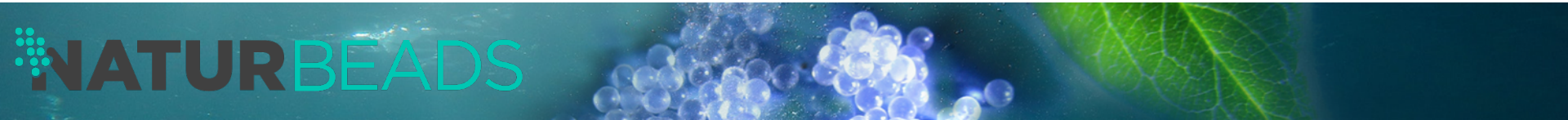
Cellulose

Abundant

Natural

Renewable

Biodegradable



Competition

High Cost

Further bans expected

Biodegradable beads (PHA)

Plastic beads (PE, PMMA, polyacrylates)

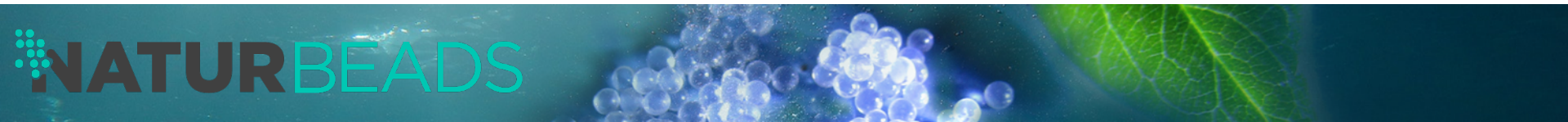
NATUR BEADS

Oats, salt, sugar, nut shells, fruits seeds

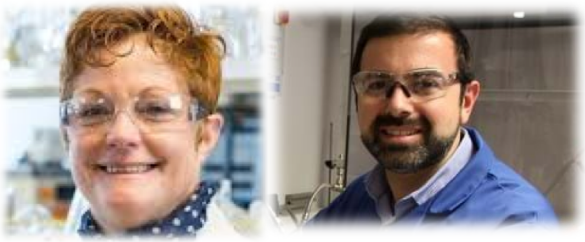
Other beads (silica, PLA)

Non-customizable

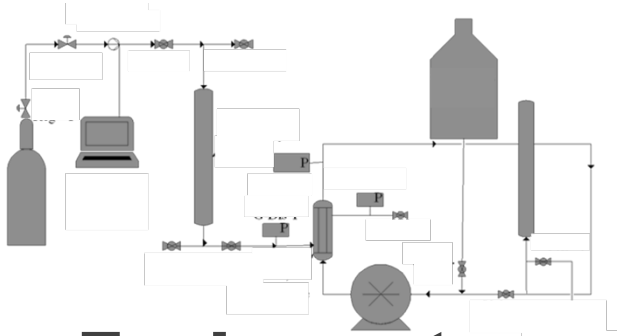
Non-biodegradable



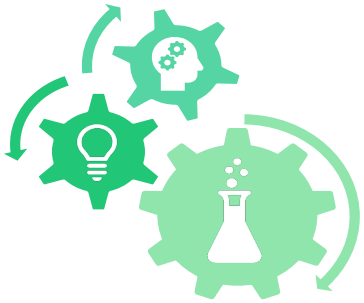
Business Model



Know-how



Equipment



Processes

Technology solution
for cosmetic ingredients and materials manufacturers

Fee + Royalties

Team

Dr Giovanna Laudisio

Co-Founder and CEO

DUPONT · BUDDING INNOVATIONS · NUS National University of Singapore

Expertise in Project Management and Technology translation

Prof. Janet Scott

Co-founder

Technology Advisor- Chemistry

UNIVERSITY OF BATH · Unilever

Expertise in biopolymers chemistry

Prof. Davide Mattia

Co-Founder

Technology Advisor-Engineering

UNIVERSITY OF BATH · EPSRC

Expertise in membrane processes

Lolan Naicker

Principal Process Engineer

sasol reaching new frontiers · dyson

Expertise in Scale up and Technology commercialization

Kantish Bhalerao

Process Technician

DUPONT · NHS

Expertise in Manufacturing, Testing, Quality control

Roger Whorrod, OBE

Business Adviser

UNIVERSITY OF BATH

Expertise in Entrepreneurship

Roadmap

Next step

Cellulose microbeads for applications beyond cosmetics. Pilot plant

Full scale plant

2019 | 2020 | 2021 | 2022 | 2023

Cellulose beads for cosmetic applications. Pilot plant

Porous, hollow, functionalized beads ...

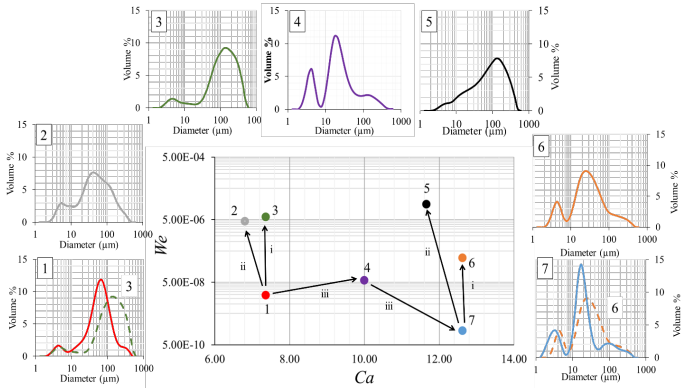
Innovate UK

sky ocean ventures

Full scale plant

Conclusions

Plastic microbeads are a scourge for the environment and have to be removed at the source as they cannot be cleaned-up.



We have developed a biodegradable alterative based on cellulose, using a continuous scalable process with good control over size, chemistry and structure.

We have created a spin-off company to industrialise the beads manufacturing process and commercialise the technology to have a real and positive impact on the environment.

NATURBEADS

Acknowledgements and Questions

BioBeads Team:

- Prof Janet Scott
- Prof Karen Edler
- Dr James Coombs
- Dr Ekanem Ekanem
- Dr Hui Shi
- Amy Wilson
- Davide Califano
- Ciarán Callaghan

Naturbeads Team:

- Dr Giovanna Laudisio
- Prof Janet Scott
- Lolan Naicker
- Kantish Bhalerao
- Roger Whorrod

University of Bath :

- Dr Ana Lanham
- Asalma Sebastian

funders:

EPSRC Engineering and Physical Sciences Research Council

Innovate UK

sky ocean ventures

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