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FACULTY OF BIOSCIENCE ENGINEERING

DEPARTMENT OF GREEN CHEMISTRY AND TECHNOLOGY[1]
DEPARTMENT OF ANIMAL SCIENCES AND AQUATIC ECOLOGY[2]

DEVELOPMENT OF MICROPLASTIC REMEDIATION TECHNIQUES FROM MARINE SEDIMENTS

Presented by Ir. Michiel Van Melkebeke[1,2]
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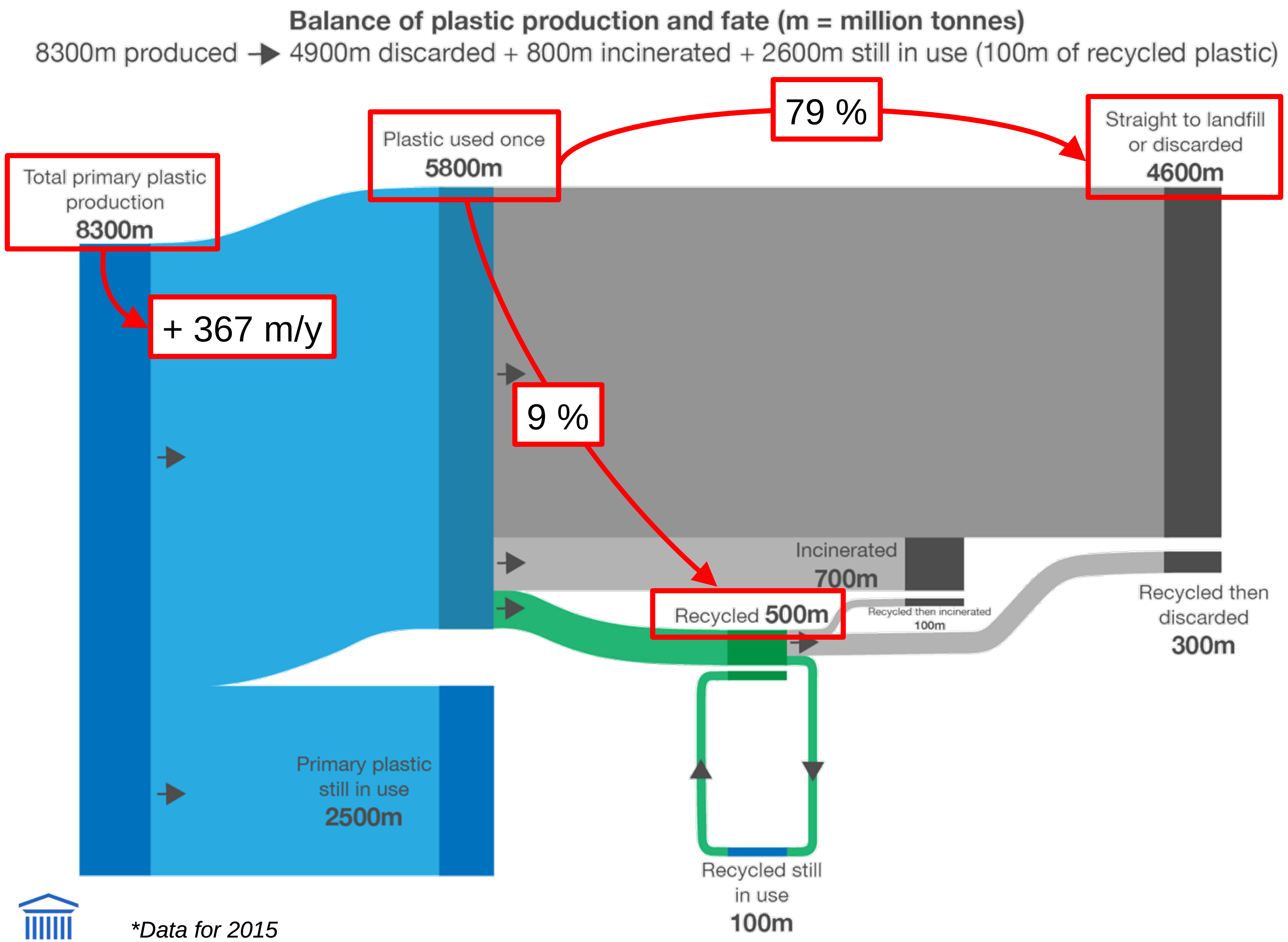
LCPE Laboratory for Circular Process Engineering

Friday 17th of June 2022
16:30 – 16:45
Room 2 Session XXII

PLASTIC POLLUTION



**Data for 2015*

Source: Geyer, Jambeck, Law. Sci. Adv. (2017) Production, use, and fate of all plastics ever made

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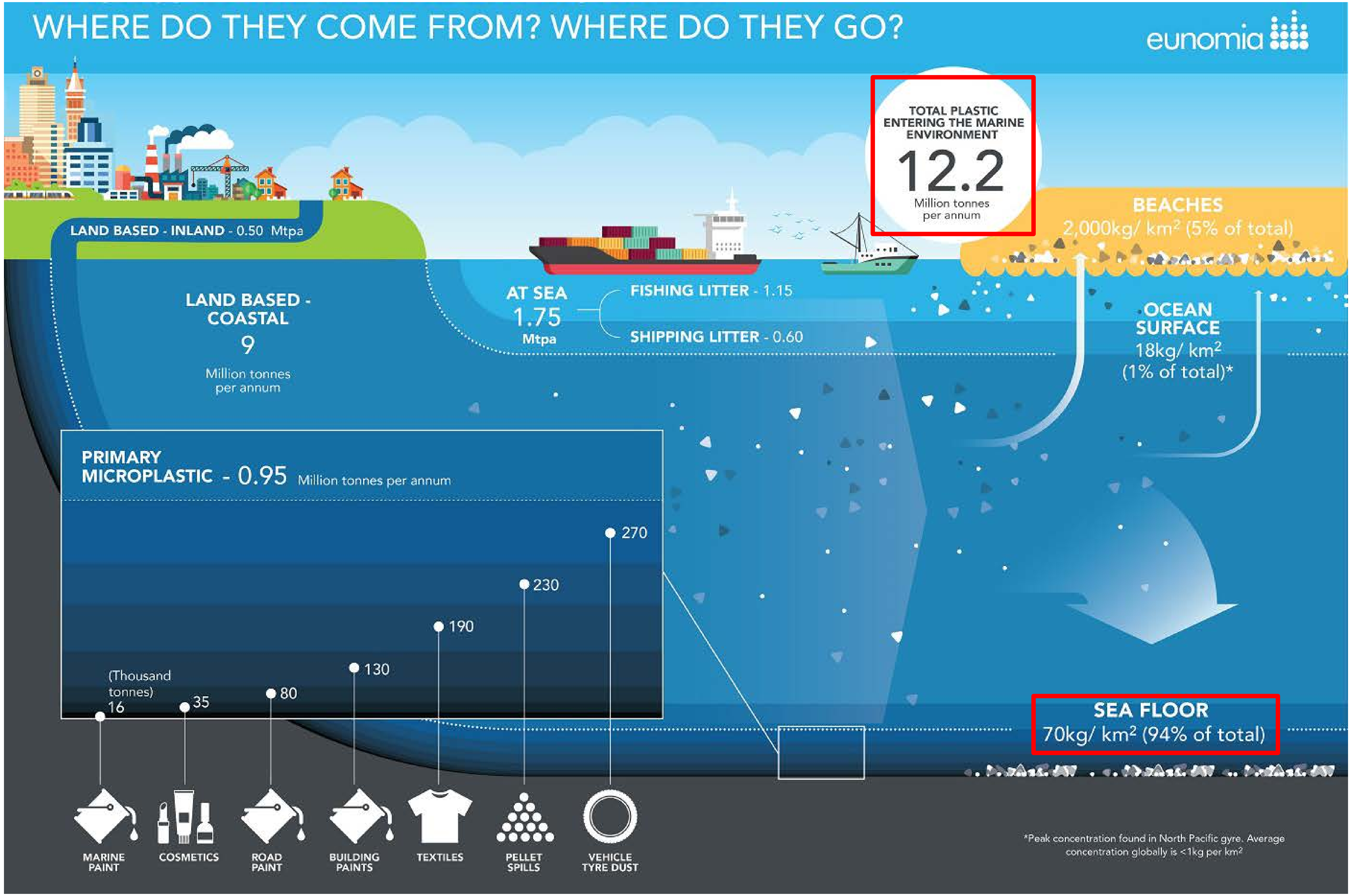
PLASTICS IN THE MARINE ENVIRONMENT



Source: Eunomia Research & Consulting Ltd. (2016) Plastics in the Marine Environment

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RESEARCH OBJECTIVE

Development of a separation technique that is able to isolate microplastics from marine sediments (during dredging operations)

1. Qualitative and quantitative feed characterisation
2. Fundamental analysis of the characteristics, sinking behaviour and surface properties of typical microplastics
3. Evaluation of proven separation techniques

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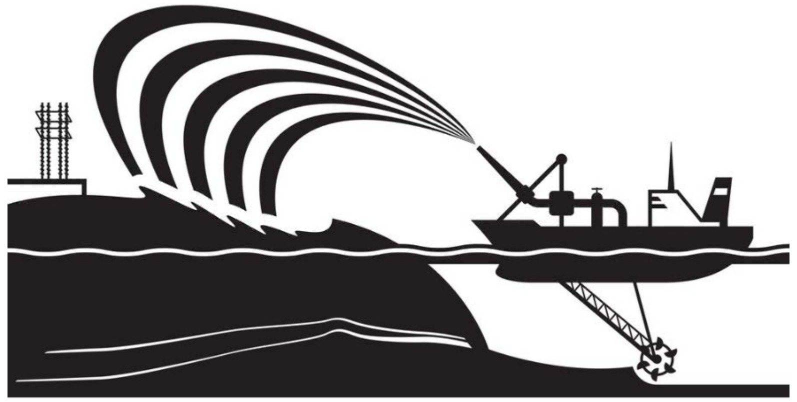
WHAT IS THE TARGET FEED?



Maintenance dredging: Scenario 1

Beach nourishments: Scenario 2

Feed constituent	Size range		Average density [kg/m³]	Contact angle* [°]
	Scenario 1	Scenario 2		
Sediment	< 63 µm	63 µm – 2 mm	2650	< 90
Low-density MPs	1 µm – 5 mm	1 µm – 5 mm	925	> 90
High-density MPs	1 µm – 5 mm	1 µm – 5 mm	1400	> 90

**contact angle > 90° = hydrophobic, contact angle < 90° = hydrophilic*

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→ Explore techniques that separate particles based on **density** and/or **polarity**

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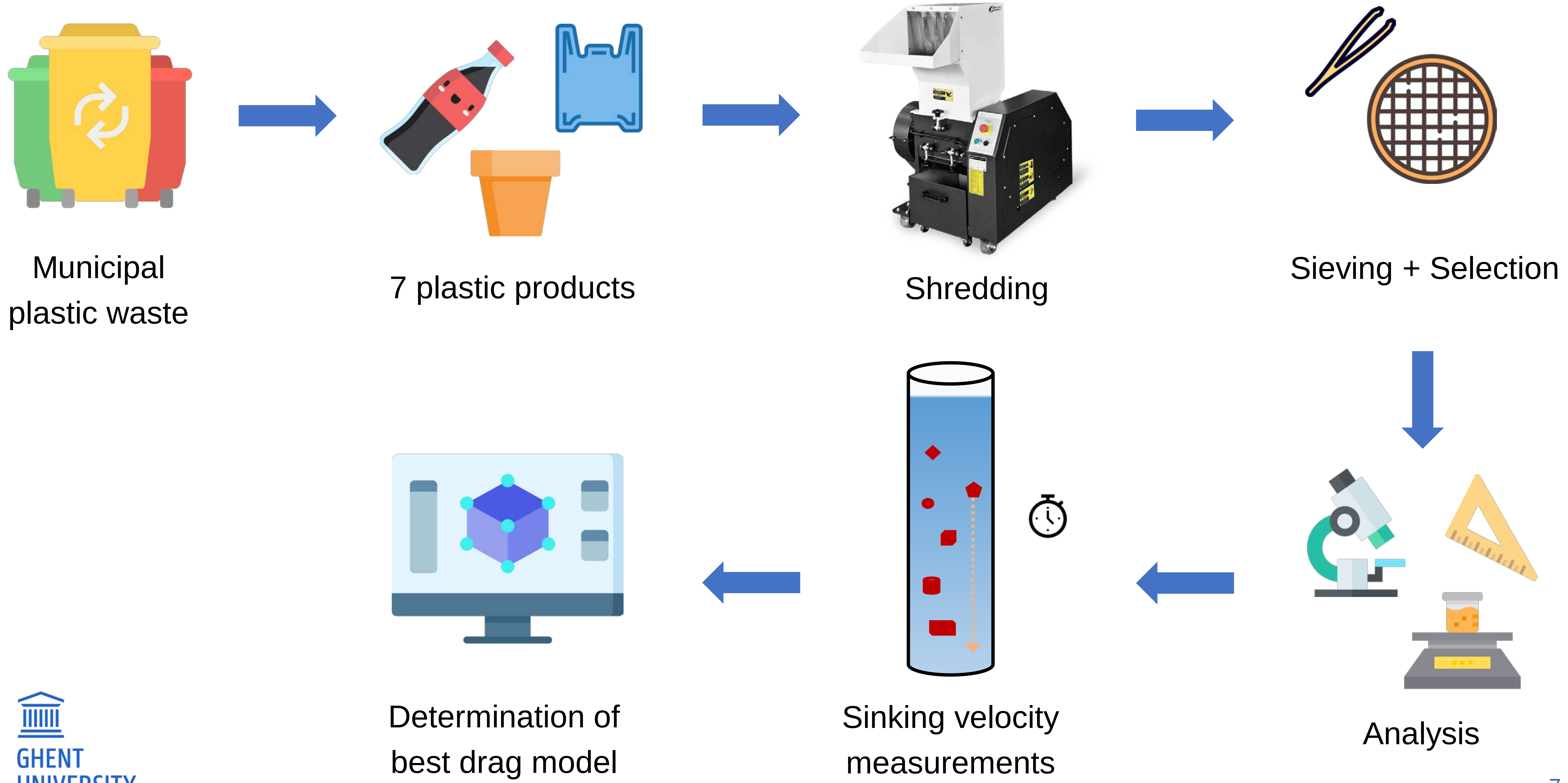
SINKING BEHAVIOUR OF MICROPLASTICS



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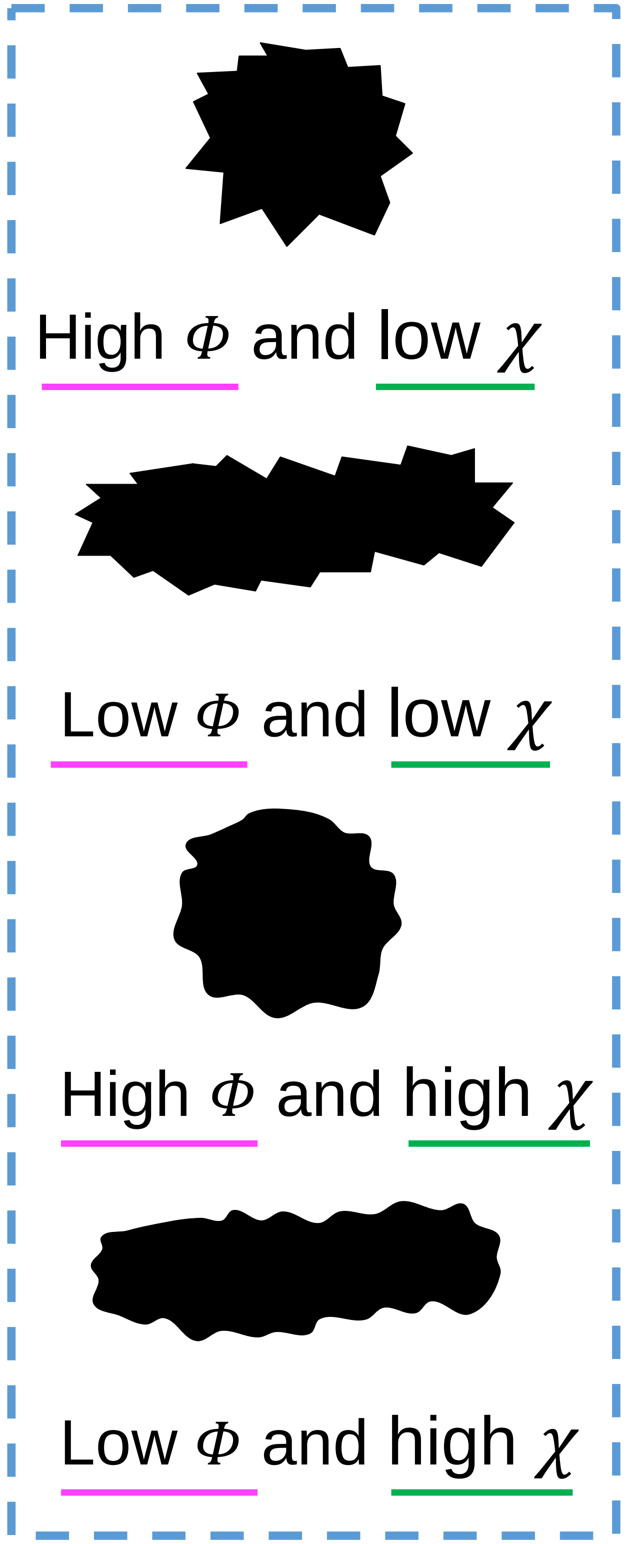
DRAG MODELS

Sphericity Φ and Circularity χ

Author(s) drag law	Shape descriptors	Average error [%]	RMSE
Dietrich (1982)	CSF, P	19.43	28.46
Haider & Levenspiel (1989)	Φ	60.53	67.41
Swamee & Ojha (1991)	β = f(CSF)	34.08	46.28
Ganser (1993)	K1 = f(Φ), K2 = f(Φ)	20.11	25.75
Dellino *et al.* (2005)	Ψ = f(Φ, χ)	23.88	30.61
Pfeiffer *et al.* (2005)	φ	48.46	59.78
Camenen (2007)	CSF, P	29.09	33.04
Dioguardi & Mele (2015)	Ψ = f(Φ, χ)	46.90	50.93
Bagheri & Bonadonna (2016)	*F*, e	21.89	27.35
Dioguardi *et al.* (2018)	**Ψ = f(Φ, χ)**	**13.20**	**19.09**

$$C_D = \frac{24}{Re_p}\left(\frac{1-\Psi}{Re_p}+1\right)^{0.25} + \frac{24}{Re_p}\left(0.1806\,Re_p^{0.6459}\right)\Psi^{-Re_p^{0.08}} + \frac{0.4251}{1+\frac{6880.95}{Re_p}\Psi^{5.05}}$$



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WHAT ABOUT BIOFOULING?

ed

fixation weight

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WHAT IS THE TARGET FEED?

Feed constituent	Size range		Average density [kg/m³]	Contact angle* [°]	Average sphericity
	Scenario 1	Scenario 2			
Sediment	< 63 µm	63 µm – 2 mm	2650	< 90	> 0.7
Low-density MPs	1 µm – 5 mm		925	> 90	0.01 – 1
High-density MPs	1 µm – 5 mm		1400	> 90	0.01 – 1
Bio-fouled MPs	1 µm – 5 mm		± 1100	< 40	0.01 – 1

**water contact angle > 90° = hydrophobic, water contact angle < 90° = hydrophilic*

➡ Selection of most promising techniques: **centrifugal sedimentation** and **froth flotation**

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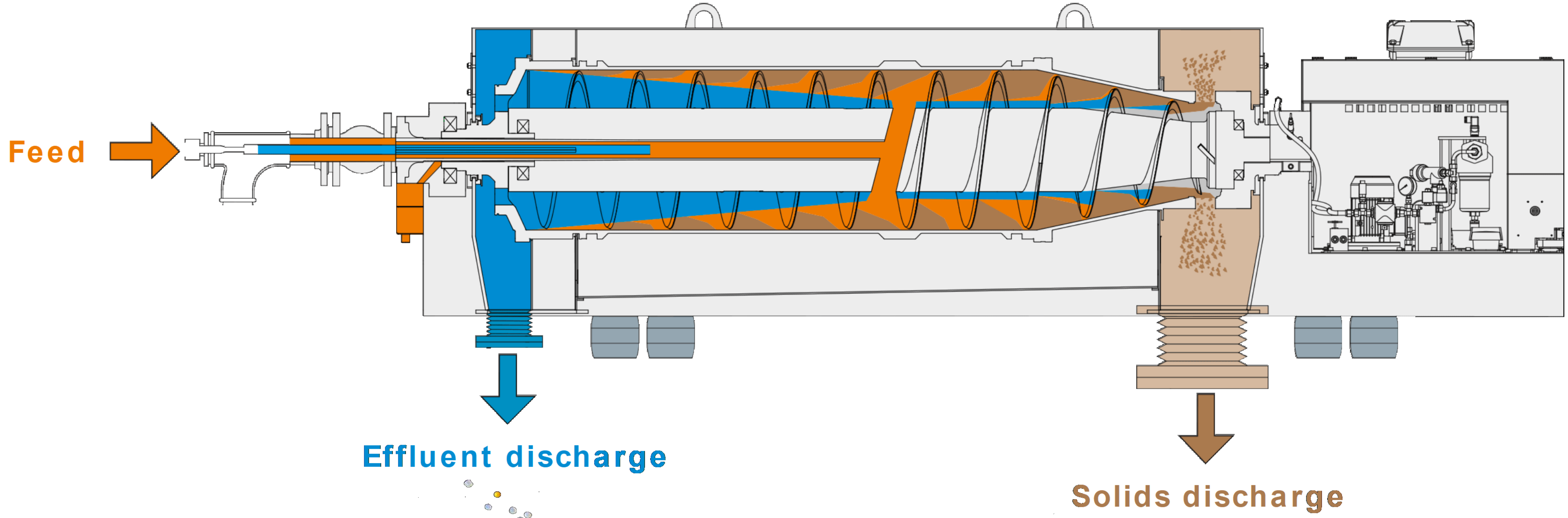
DOES CENTRIFUGAL SEDIMENTATION WORK?

$$u_t = \frac{d_p^2 \, |\rho_p - \rho_f| \, \boldsymbol{g}}{18 \, \mu}$$

$$u_c = \frac{d_p^2 \, |\rho_p - \rho_f| \, \boldsymbol{\Omega}^2 \, \boldsymbol{r}}{18 \, \mu}$$



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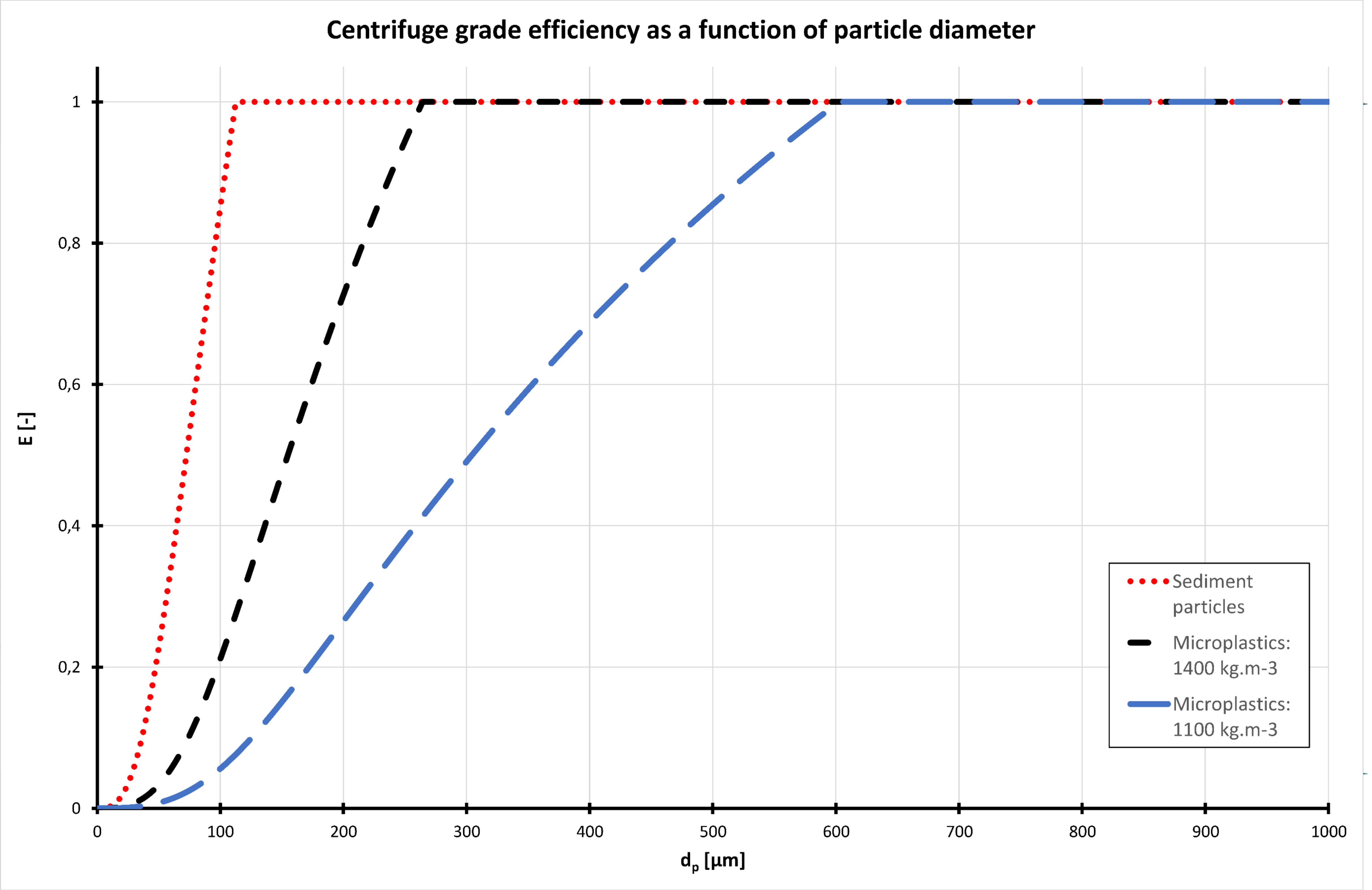
CENTRIFUGE GRADE EFFICIENCY CURVES



Effluent discharge

Effluent discharge

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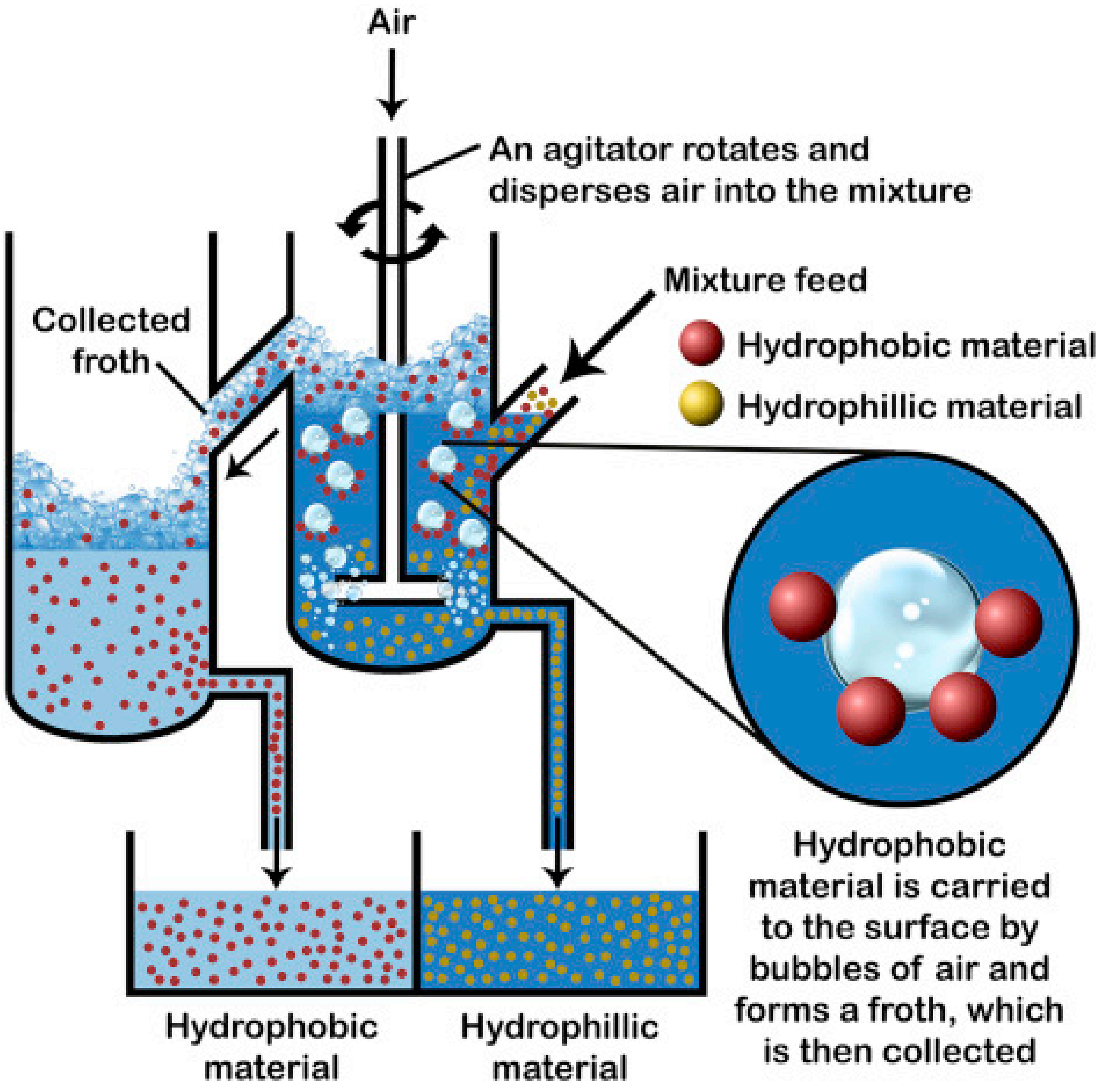
WHAT ABOUT FROTH FLOTATION?

Promising…

- Based on difference in polarity
- Microplastics separated in a concentrated stream

…but practical issues in traditional setups

- How to deal with sediment (clogging)?
- How to create optimal air bubble flows?
- How to increase system flexibility?



Source: Crawford C. B and Quinn B. Microplastic separation techniques. In Microplastic Pollutants, p. 203–218. Elsevier, 2017.

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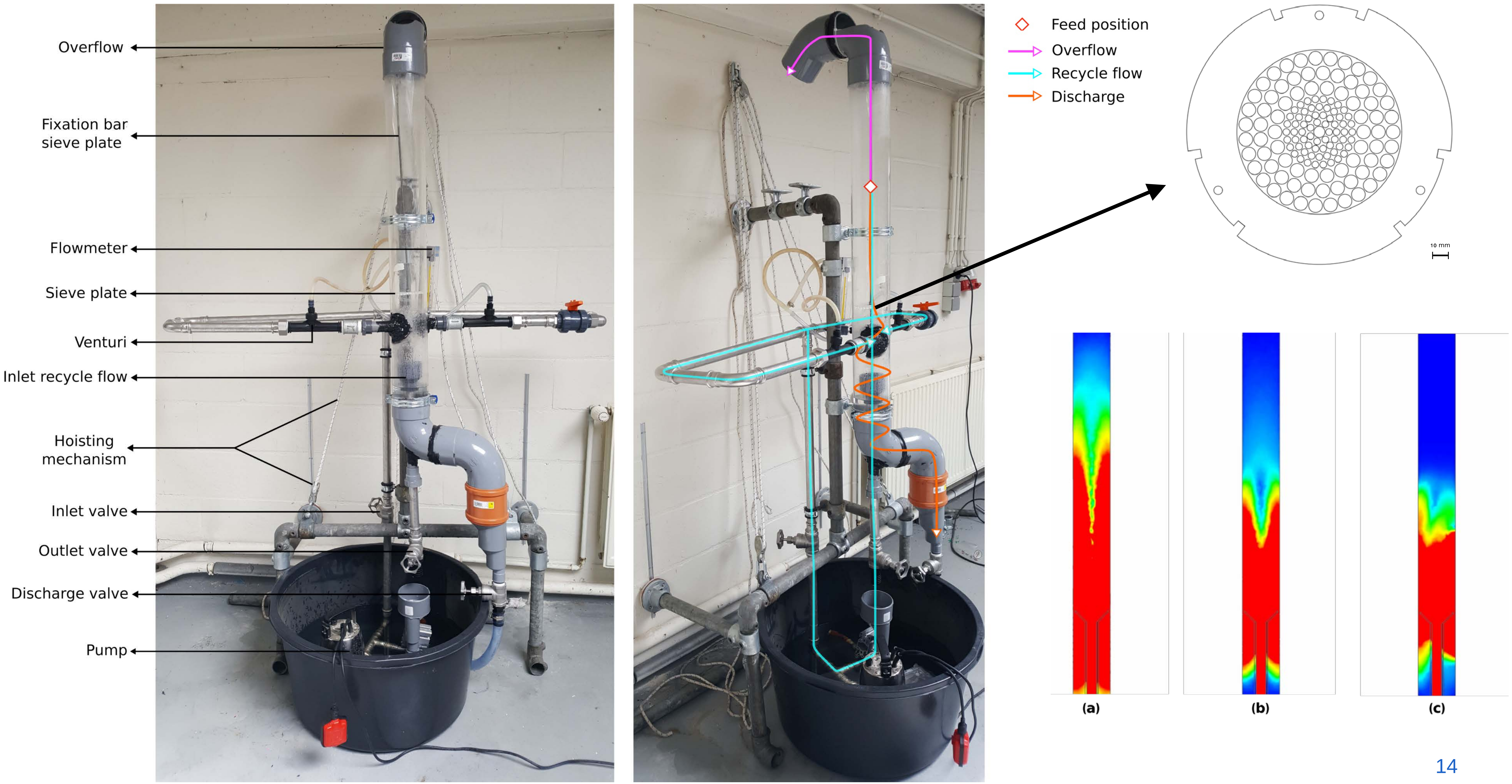
DESIGN OF A NOVEL INSTALLATION



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PROMISING RESULTS

Microplastic recovery rate / Sediment entrainment	
High-concentration feed (1000:1)	
Low-density microplastics	100%
High-density microplastics	> 95%
Sediment - Scenario 1 - Scenario 2	 ± 5.0 m% ± 0.1 m%
Average-concentration feed (100:1)	
Low-density microplastics	100%
High-density microplastics	± 85%
Sediment - Scenario 1 - Scenario 2	 ± 5.0 m% ± 0.1 m%

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WHAT IS NEXT?

Development of a separation technique that is able to isolate microplastics from marine sediments (during dredging operations)

1 Upscale of pilot installation

2 Integration on dredging vessel

3 Economic analysis

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