Can we use theoretical approaches from natural sediment to describe the transport behaviour of microplastics?

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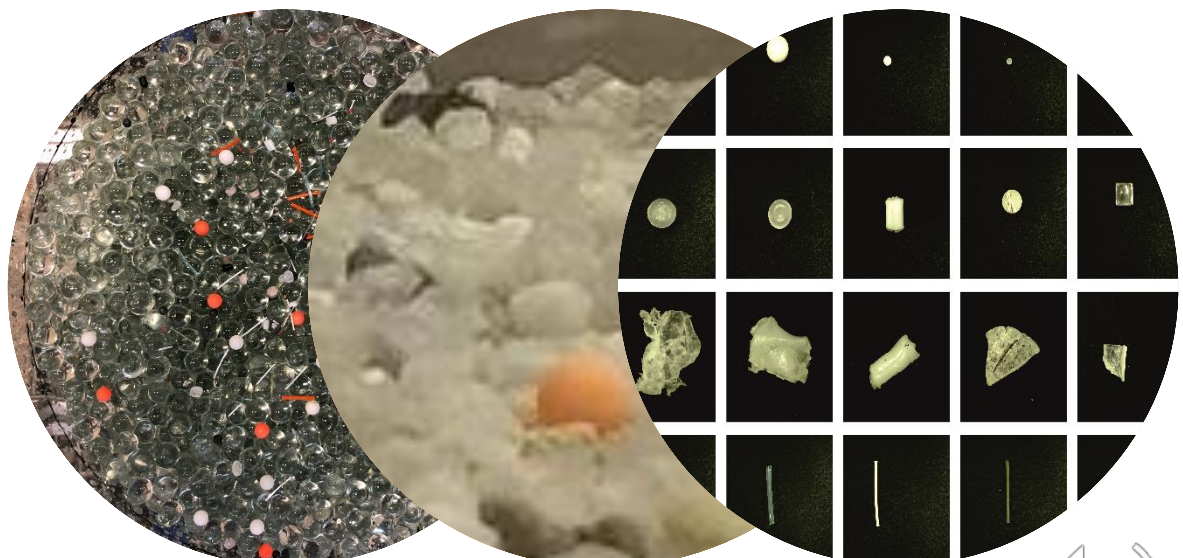

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Microplastics are everywhere.

But how are they transported in the environment?

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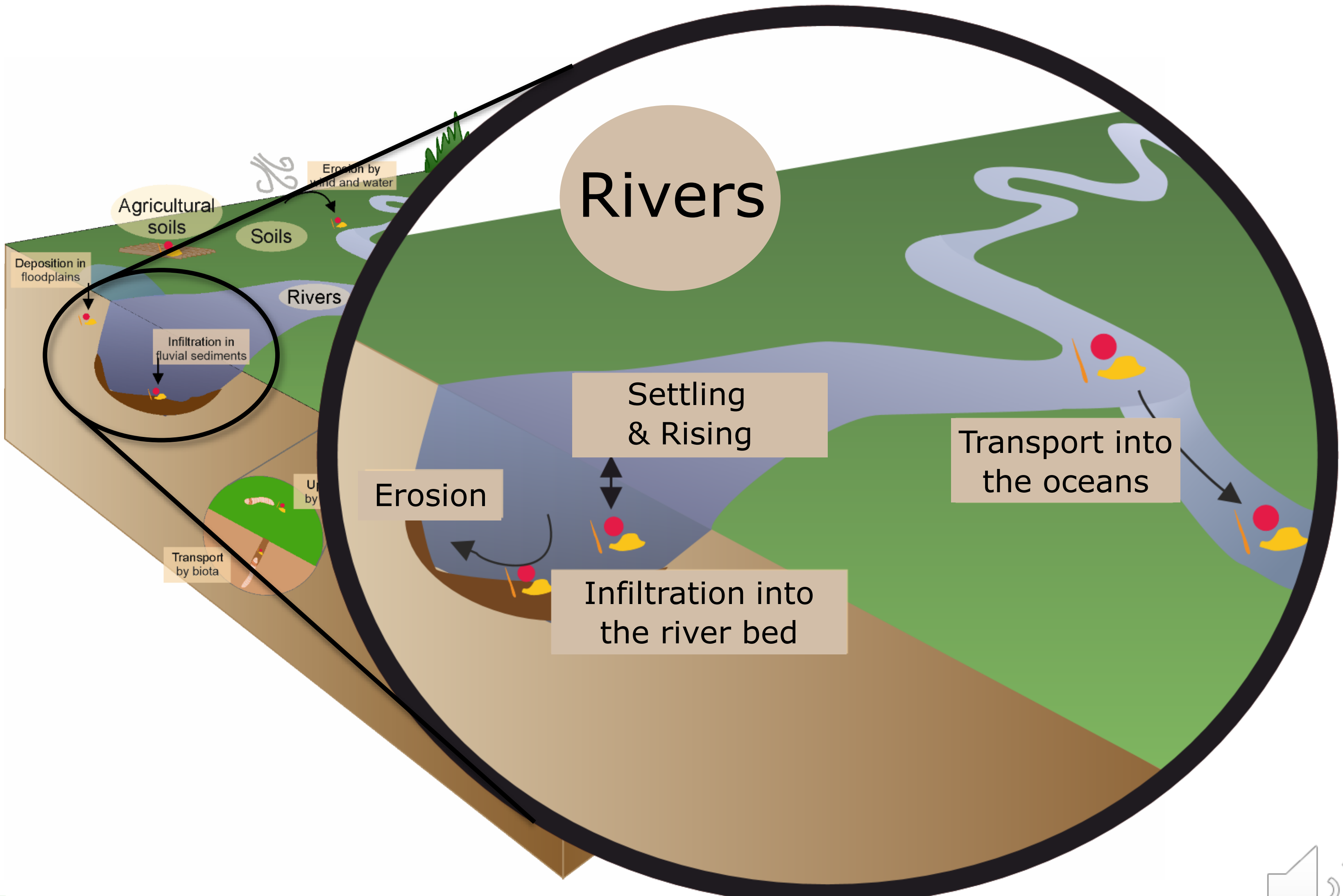
Transport pathways and sinks



Microplastics = Natural sediments?

Comparison of Particle Properties

Microplastics	Natural Sediments
Density: 0.02 – 2.3 g/cm³	Density: 2.65 g/cm³
Diameter: 0.001 – 5 mm	Diameter: Clay: < 0.004 mm Silt: 0.004 – 0.063 mm Sand: 0.063 – 2 mm Gravel: 2 – 63 mm
Shape: Pellets, fragments, fibers, foams, foils, microbeads	Shape: Granular

We need prove!

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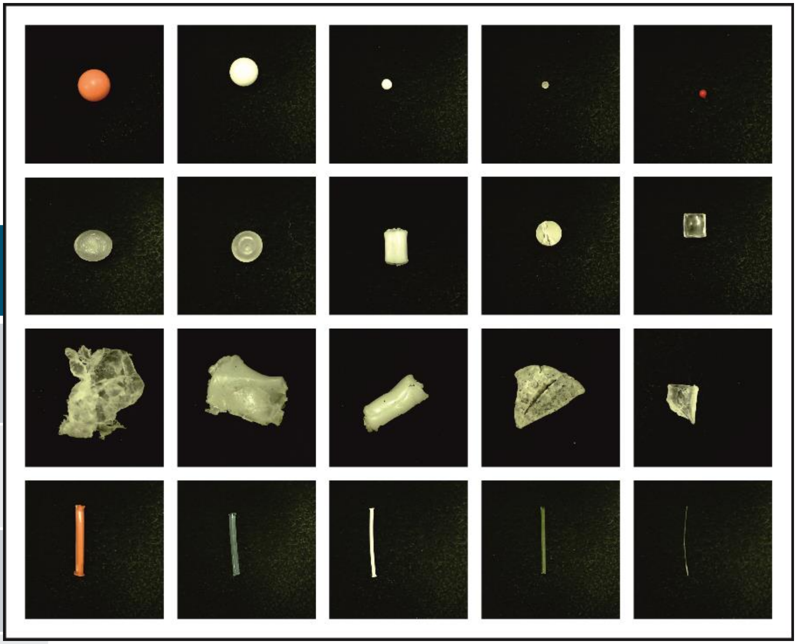
Microplastic Particles

Polymer		Shape	Density [kg/m³]
Polypropylene	PP	Sphere, pellet, fiber, fragment	826-870
Polyethylene	PE	Sphere, pellet, fiber, fragment	894-936
Polystyrene	PS	Sphere, pellet, fragment	1008-1021
Expanded Polystyrene	EPS	Sphere (foamed)	22
Polyvinyl-chloride	PVC	Pellet, fragment	1307
Polyethylene-terephthalate	PET	Pellet, fiber, fragment	1368
Polyamide	CoPA	Fiber	1101-1107



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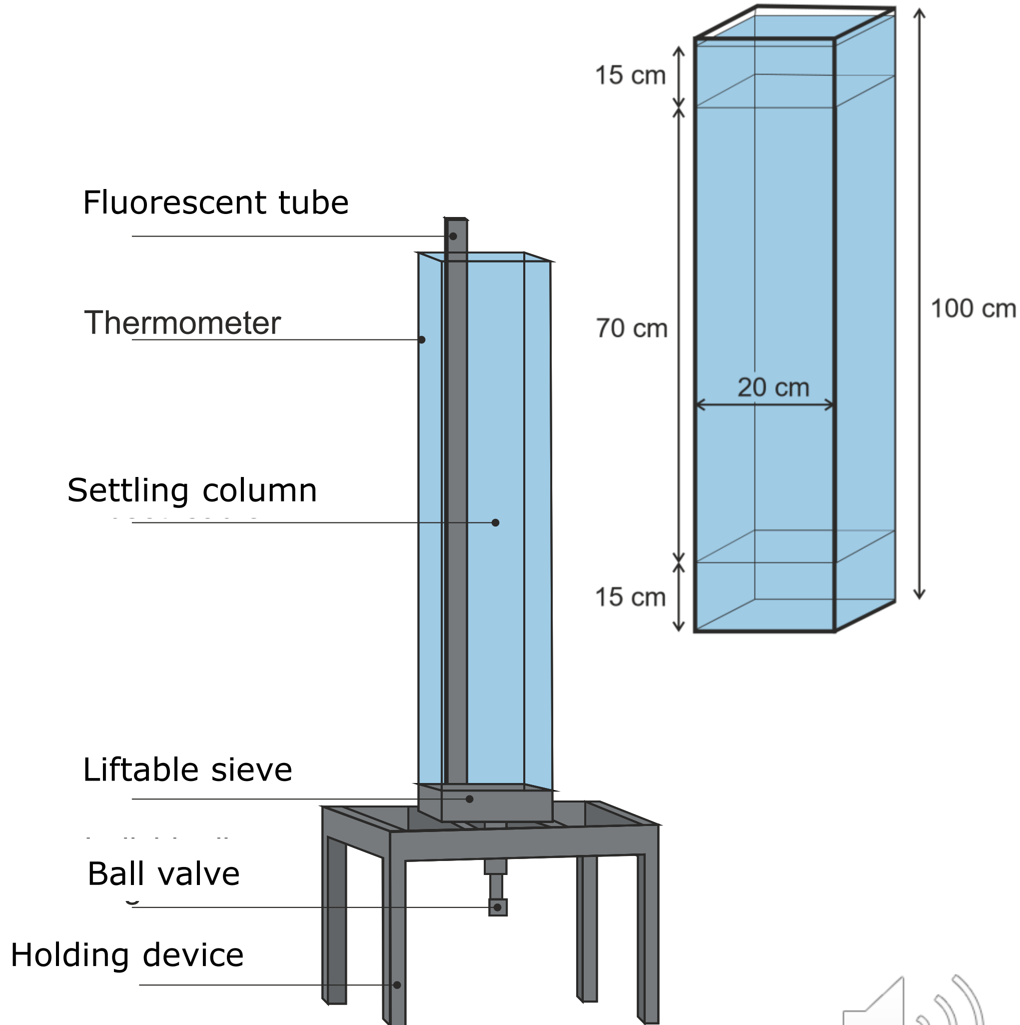
Settling & Rising: Experimental Setup

- Settling column with an opening at the top and at the bottom
- 15 cm each for accelerating the particles
- 2 x 35 cm measuring section
- Measurements with a camera
- 52 different MP particles
- 468 runs



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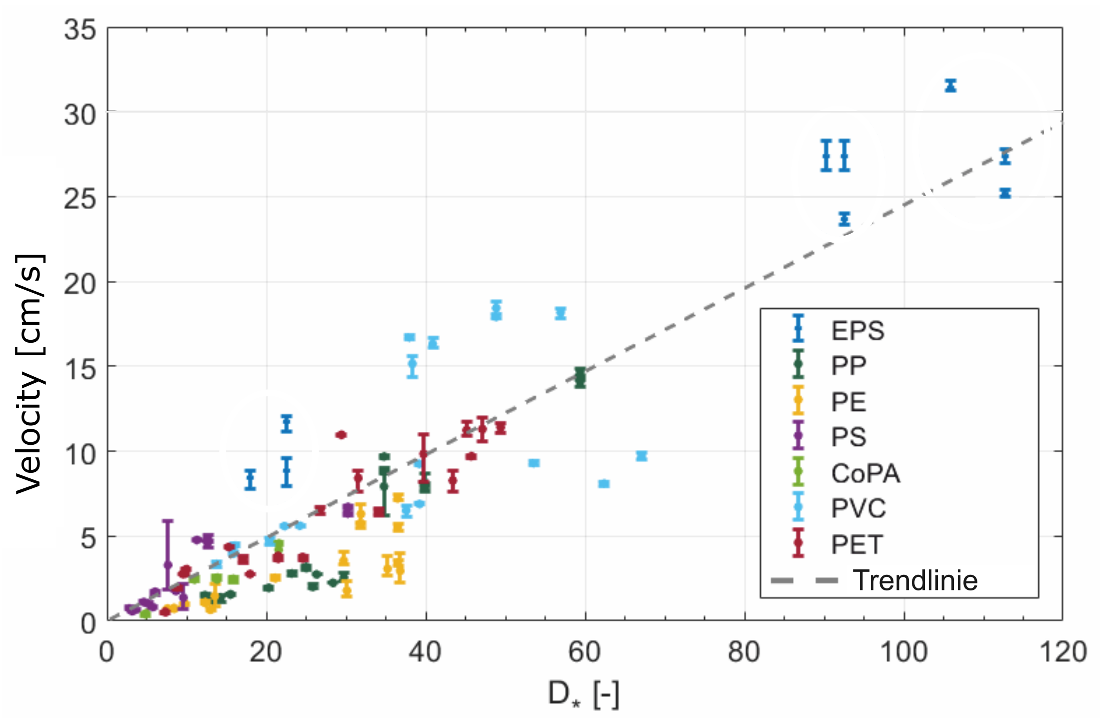
Settling & Rising: Results



$$\Delta = \frac{|\rho_{Water} - \rho_{Particle}|}{\rho_{Water}}$$

$g = Gravitational\ acceleration$ [m/s²]

$$D_* = \left(\frac{\Delta g}{v^2}\right)^{\frac{1}{3}} d_{equi}$$

$v = Kinematic\ Viscosity\ [m^2/s]$

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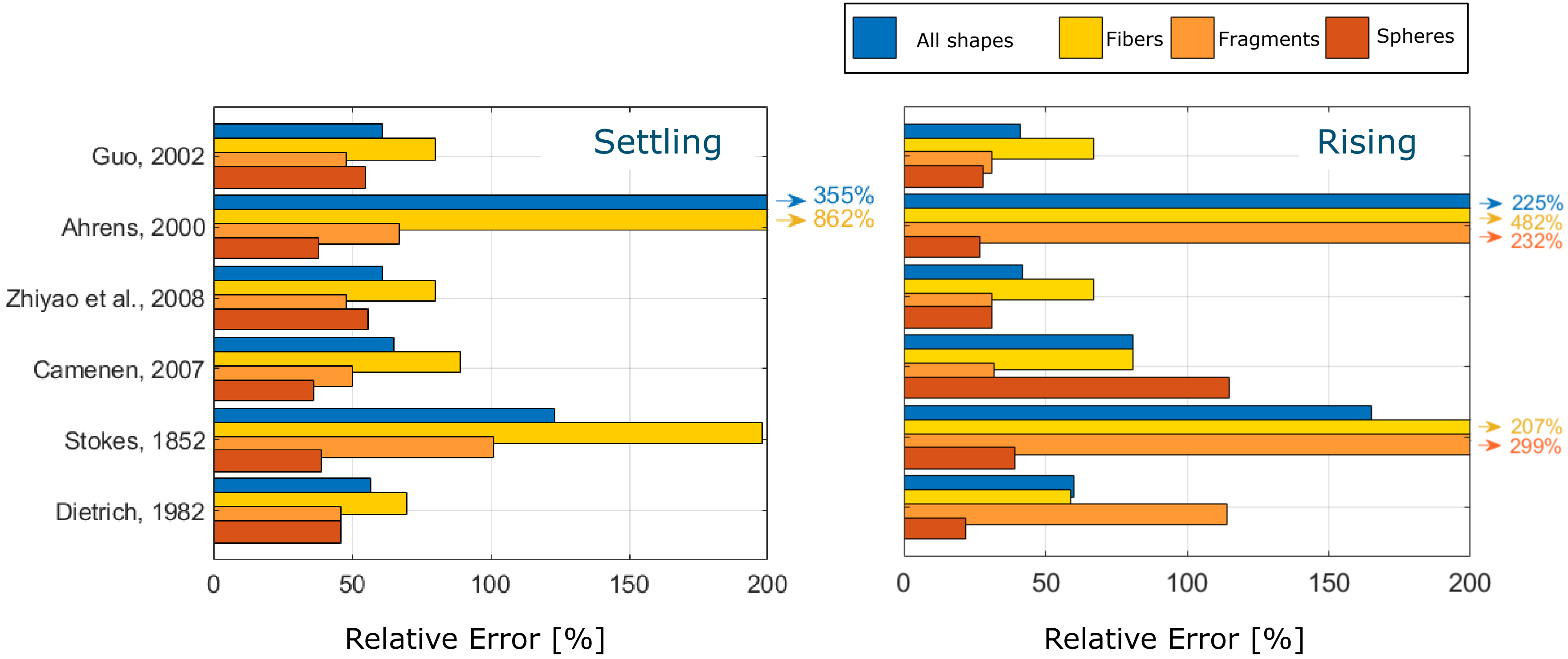
Settling & Rising: Comparison to Sedimentological Theory



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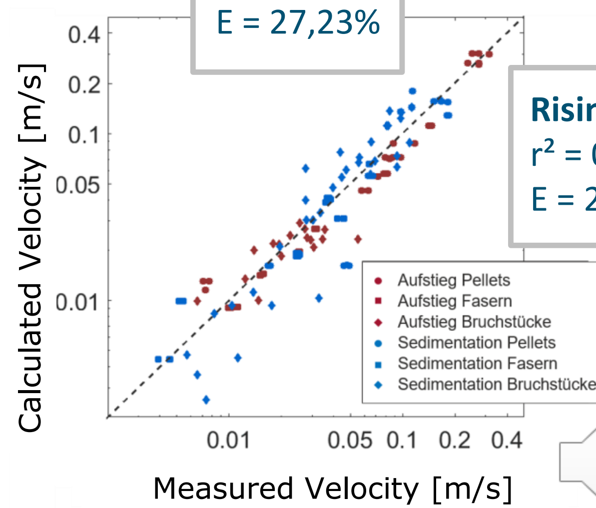
Settling & Rising: New Theoretical Approaches

	Settling	Rising
Pellets and Fragments	$C_{D,s,p+f} = \left(\frac{3}{CSF \times \sqrt[3]{Re}}\right)$	$C_{D,r,p+f} = \left(\frac{20}{Re} + \frac{10}{\sqrt{Re}} + \sqrt{1.195 - CSF}\right) \times \left(\frac{6}{P}\right)^{1-CSF}$
Drag Coefficient Fibers	$C_{D,s,fibre} = \left(\frac{4.7}{\sqrt{Re} + \sqrt{CSF}}\right)$	$C_{D,r,fibre} = \left(\frac{10}{\sqrt{Re} + \sqrt{CSF}}\right)$
Velocities	$w_s = \sqrt{\frac{4}{3}\frac{d_{equi}}{C_D}\left|\frac{\rho_s - \rho}{\rho}\right| g}$	

Settling:
r^2 = 0,83
E = 27,23%

Rising:
r^2 = 0,97
E = 20,38%



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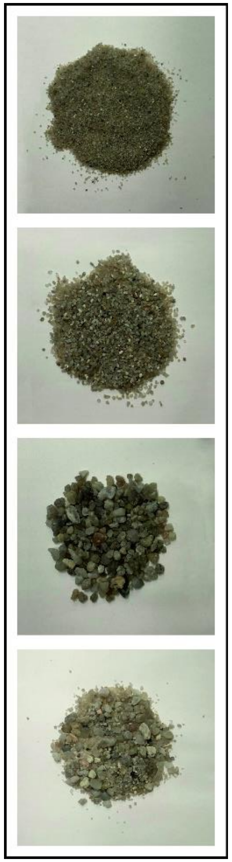
Resuspension: Experimental Setup

- 15 different MP types
- 620 experimental runs

D_{50} [mm]



0,45

0,98

3

1,48

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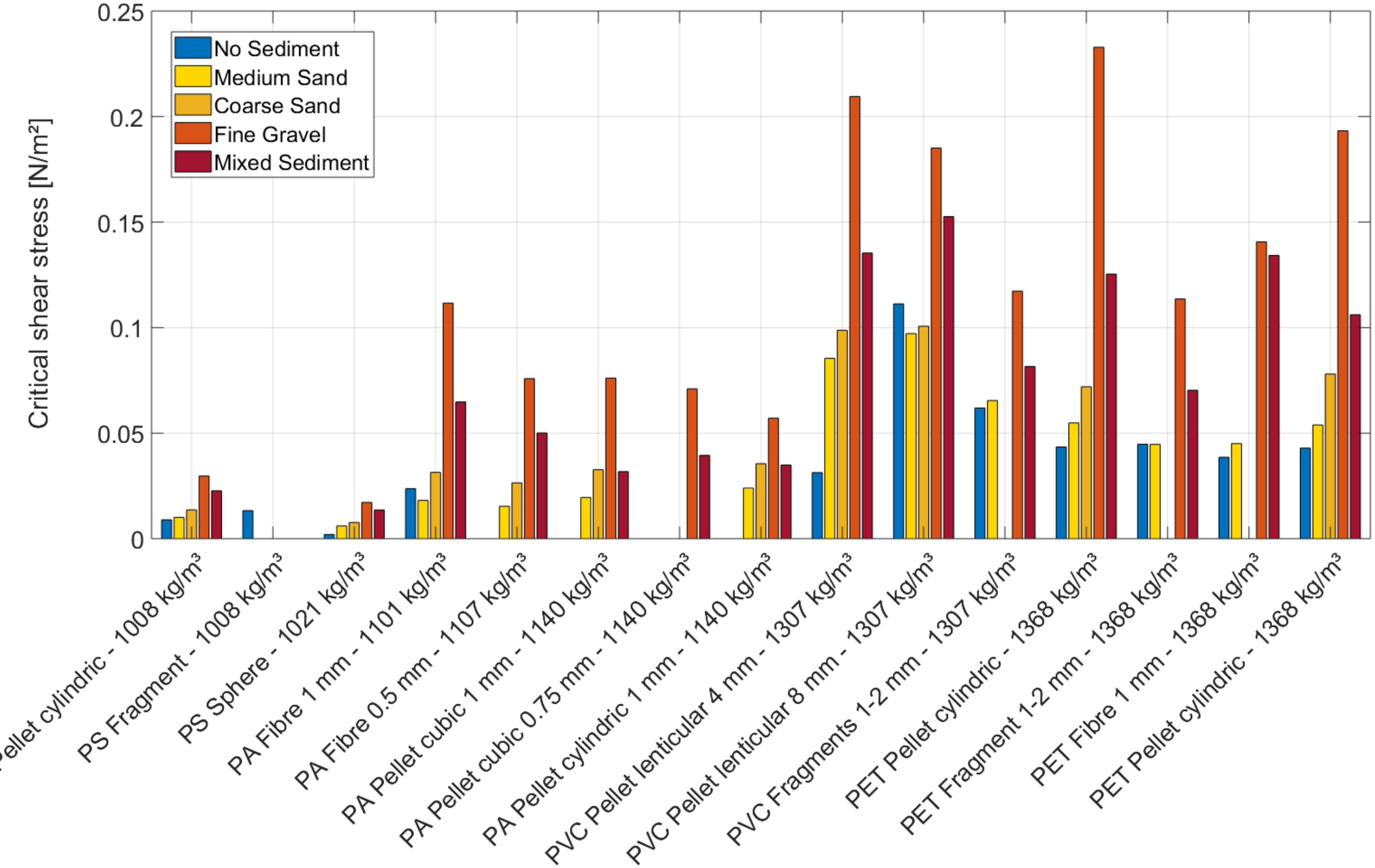
Resuspension: Results



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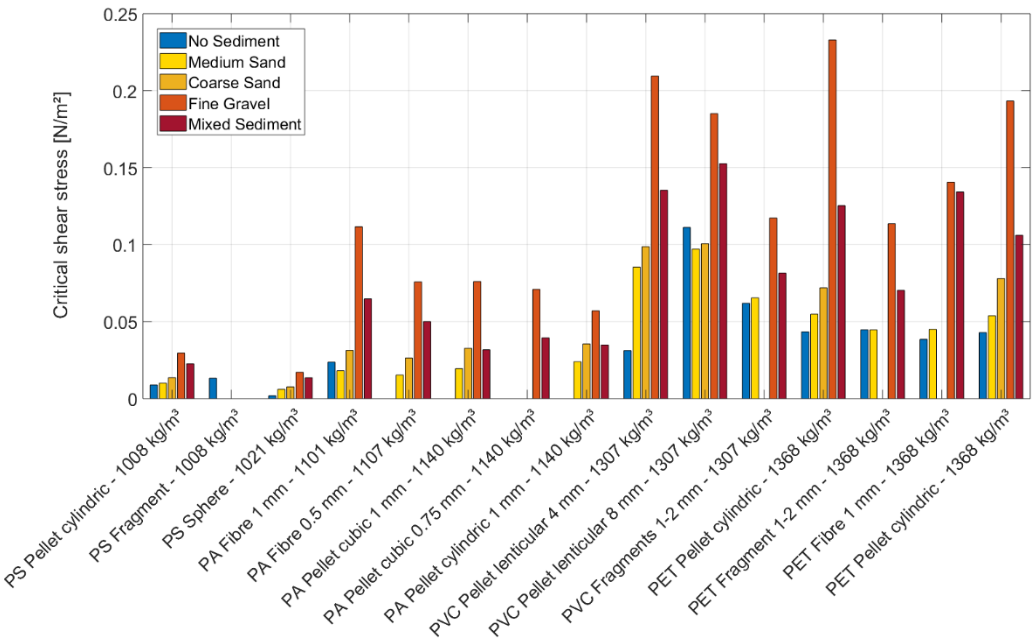
Resuspension: Results



MP density → **Shear stress**

Sediment diameter → **Shear stress**

MP diameter → **Shear stress**

MP shape → **Shear stress**

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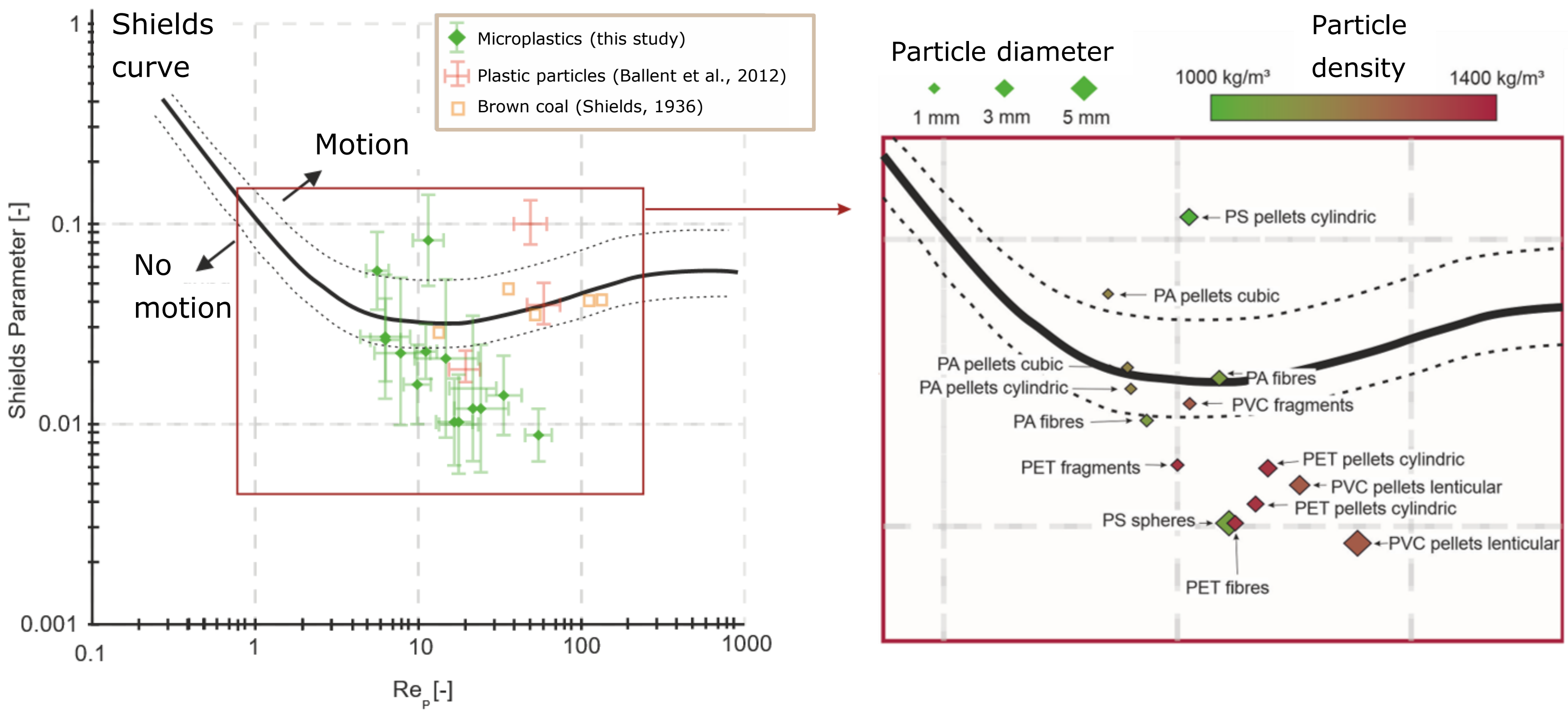
Resuspension: Comparison to Sedimentological Theory



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Resuspension: New Theoretical Approaches

Based on the hiding-exposure effect:

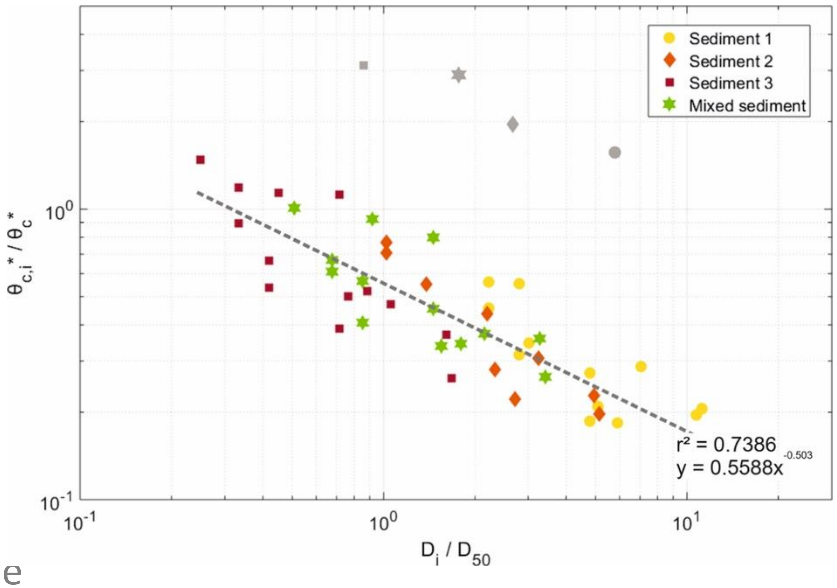
Particle diameter of the microplastics [m]

Critical Shields parameter for microplastics

$$\theta^*_{c,i} = 0{,}5588\ \theta^*_c \left[\frac{D_i}{D_{50}}\right]^{-0{,}503}$$

Critical Shields parameter for the sediment bed

Particle diameter of the sediment bed [m]



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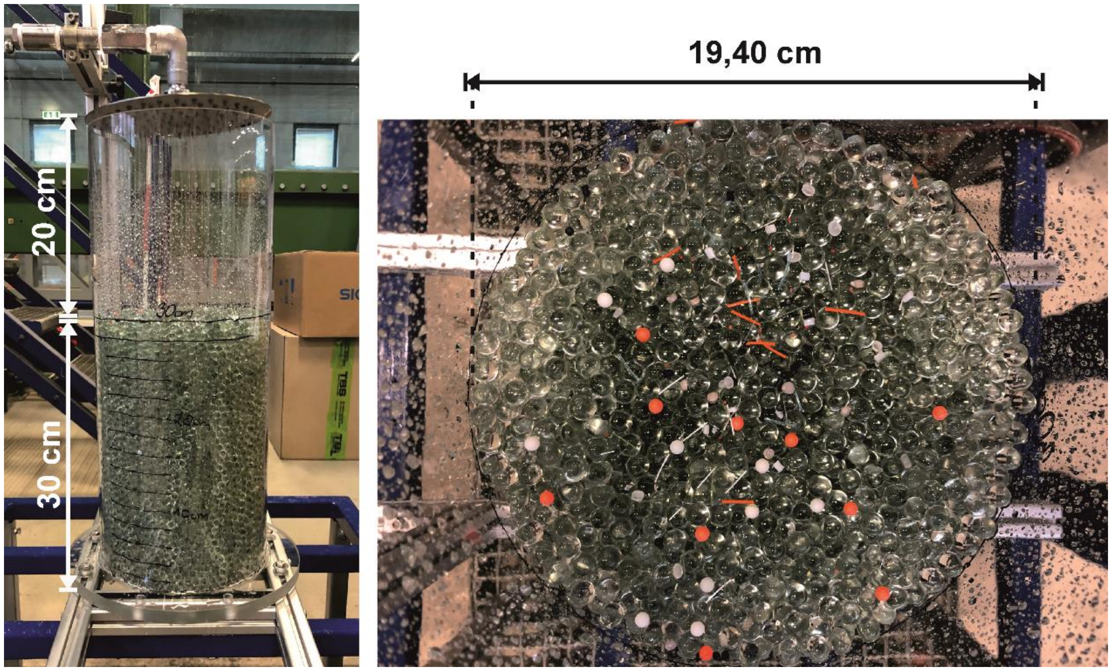
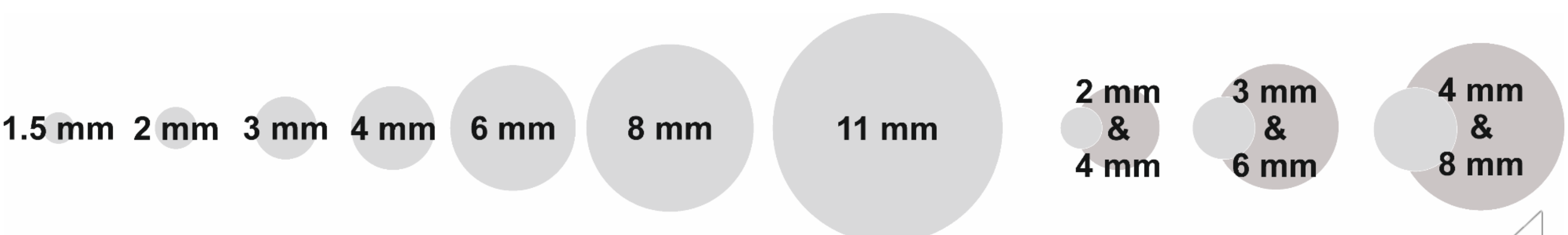
Infiltration: Experimental Setup



- 21 different microplastic particles
- Irrigation with 4600 ml/min for 1 hour



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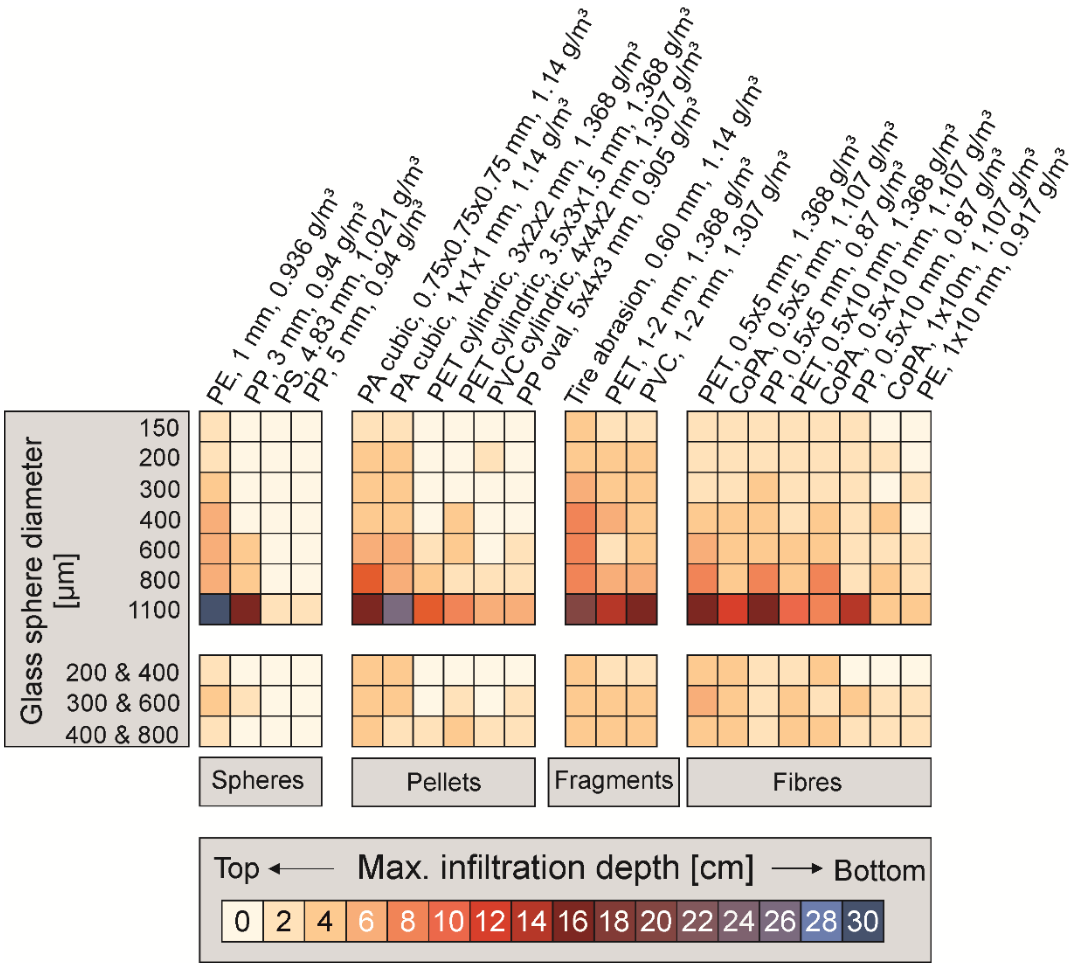
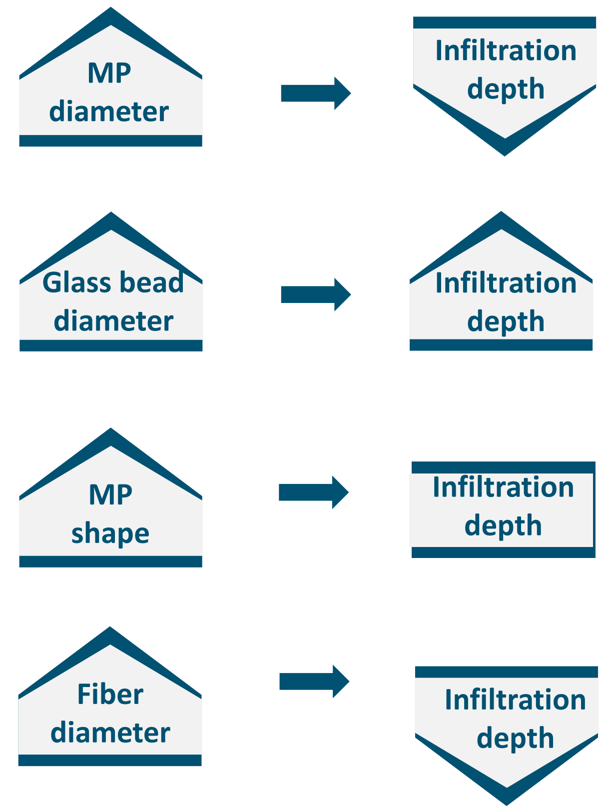
Infiltration: Results





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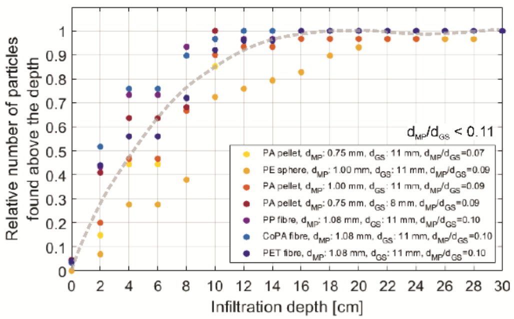
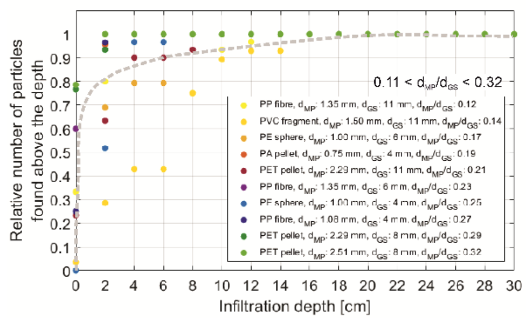
Infiltration: Comparison to Sedimentological Theory

Fine sediment infiltration: Ratio of particle diameter of infiltrating sediment (d_u) to the diameter of the sediment bed (D_u) influences infiltration depth and type

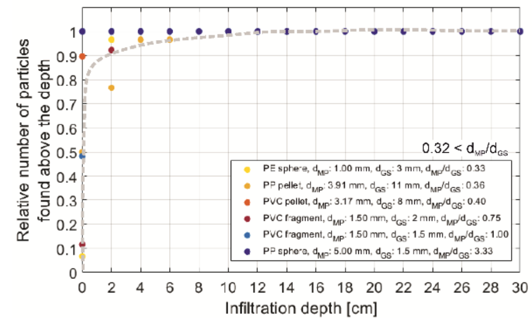
d_u/D_u < 0,11:
Unimpeded Static Percolation



0,11 < d_u/D_u < 0,32:
Finite Depth Infiltration



d_u/D_u > 0,32:
Fine Surface Sealing



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Infiltration: Application of the Results

Determination of the possible infiltration depth as a function of the microplastic size and the grain size of the existing soil.

Depth profiles of microplastic concentrations in soils rather useful for $d_u/D_u < 0{,}11$.

	Classification	Upper sediment grain size [mm]	MP size					
			100 nm	1 µm	10 µm	100 µm	1 mm	5 mm
Sediment	Coarse silt	0.063						
	Fine Sand	0.2						
	Medium sand	0.63						
	Coarse sand	2						
	Fine gravel	6.3						
	Medium gravel	20						

Average infiltration depths :	$d_{MP}/d_{sediment} < 0.11$	$0.11 < d_{MP}/d_{sediment} < 0.32$	$d_{MP}/d_{sediment} > 0.32$
	13 cm	5 cm	1 cm

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			MP size					
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	$d_{MP}/d_{sediment} < 0.11$	$0.11 < d_{MP}/d_{sediment} < 0.32$	$d_{MP}/d_{sediment} > 0.32$
Average infiltration depths :	13 cm	5 cm	1 cm

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We need to be careful when using sedimentological basics for describing microplastic transport!

If you are interested in a deeper discussion of my research or a collaboration, feel free to contact me!

Thank you for your attention!

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