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Morphology-dependent transport of PVC microplastic fragments in saturated quartz sand columns

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Research Goals: Transport of Microplastics in Soil

Vertical transportation and infiltration patterns of microplastics in the soil is not experimentally reproducible.

- Standard protocol to quantify and qualify microplastic particles in environmental samples.
- Define particle size and principal dimensions of non-spherical particles.
- Describe and parameterize the impact of different shapes and deformability of microplastic particles on their transport behaviour.
- Standardize descriptions of microplastic particles.

Degradation and Fragmenation

1. Chemical degradation: UV irradiation, biodegradation, and hydrolysis.

2. Mechanical fragmentation: Mechanical abrasion against sand grains.

- Resultant microplastic fragments in the environment represent a heterogeneous range of shapes, polymers, sizes, and concentrations.
- A series of ageing and fragmentation behaviours promote the transport of microplastics.
- Accelerated vertical transport depends on particle size, type, and shape.

Plastic degradation and fragmentation (Harrison, et al., 2022).

Degradation and Fragmenation

Do microplastics follow similar transport patterns to sediments?

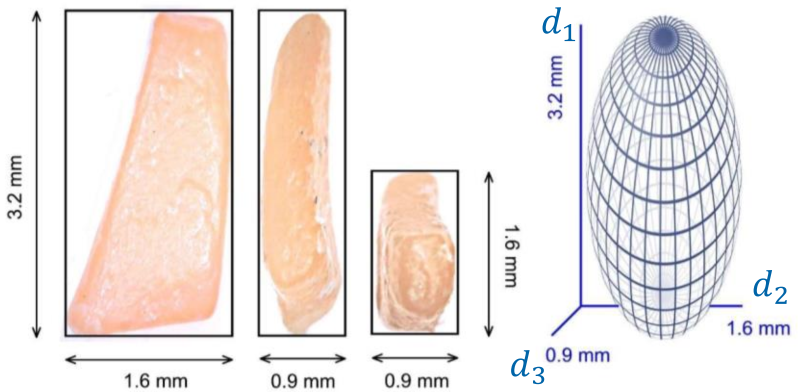
	Microplastics	Mineral sediments
Size:	0.001 - 5 mm	clay: < 0.004 mm silt: 0.004 - 0.063 mm sand: 0.063 - 2 mm gravel: 2 - 63 mm
Density:	0.02 - 2.3 g/cm³	2.65 g/cm³
Shape:	pellets, fragments, fibers, foams, foils	granular

Motivation

<u>Hypothesis:</u> The particle's morphological shape is directly related to its fate in the environment.

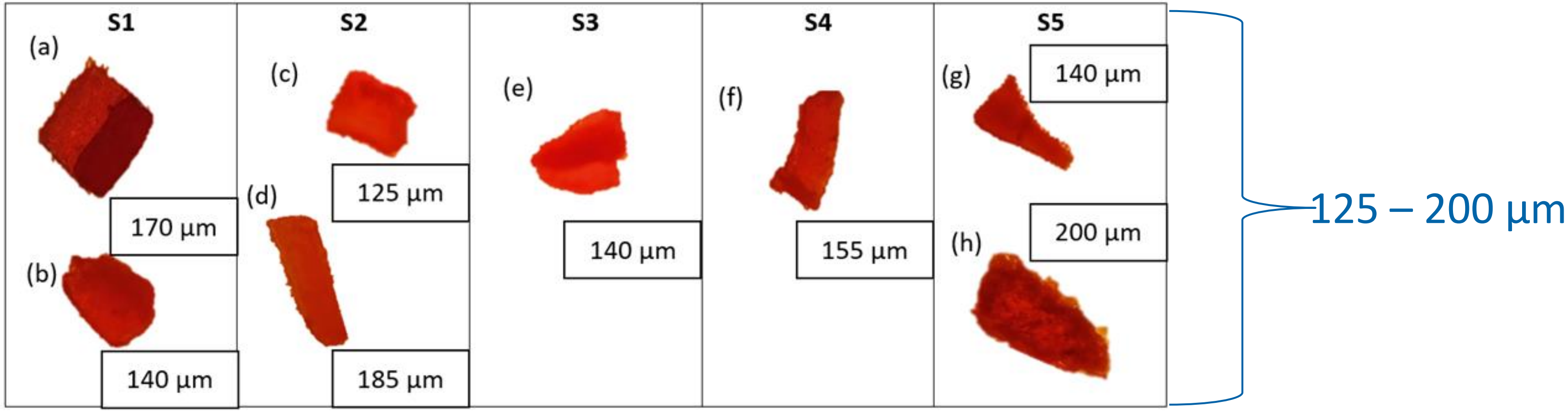
<u>Aim:</u>

- Catalogue fragments based on three-dimensional shape descriptors.
- Investigate morphology-dependent transport and retention of PVC microplastic fragments in saturated quartz sand columns.



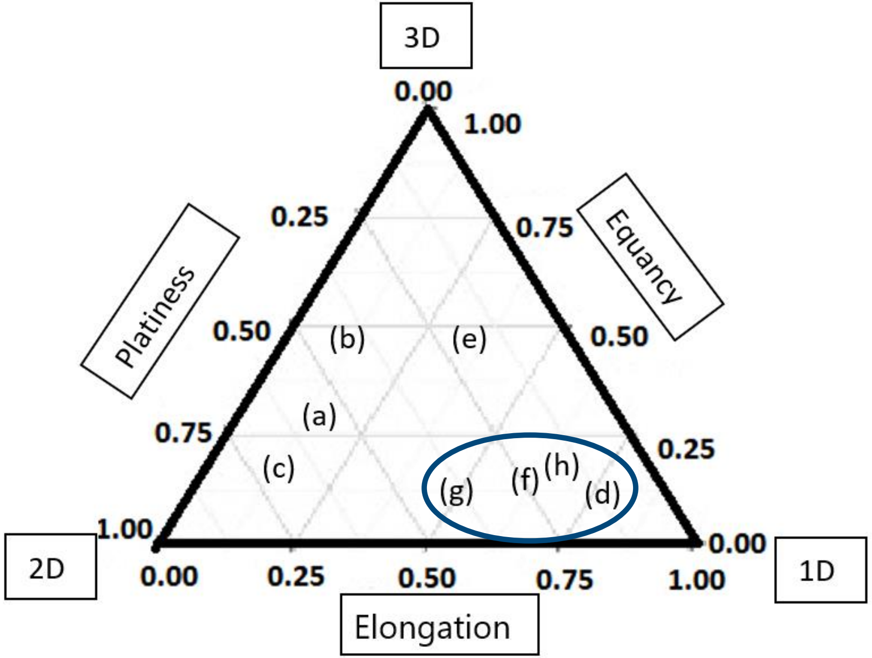
Parametrization of a microplastic fragment (Rosal 2021).

Parametrization of Morphology

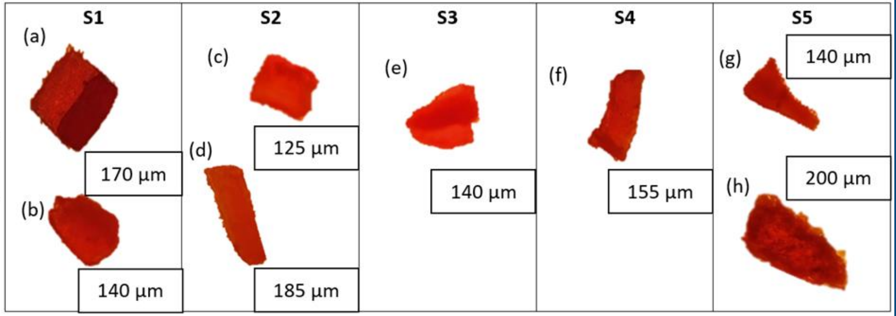


- To categorize the particles into three basic shapes, spheres (3-D), plates and films (2-D) and fibers and rods (1-D), the dimensionless parameters equancy, platiness and elongation were defined.
- The length of the fragments was measured (longitudinal, d_1), width (longest dimension perpendicular to d_1, d_2), and height (shortest dimension perpendicular to d_1, d_3).

Morphologies fit in a Barycentric Plot

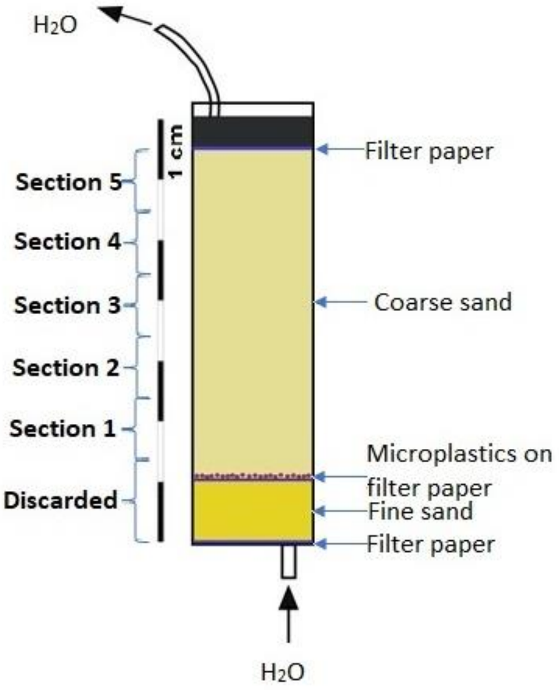


- Equancy = $\frac{d_3}{d_1}$
- Platiness = $\frac{d_2 - d_3}{d_1}$
- Elongation = $1 - \frac{d_3}{d_1}$



Barycentric plot [left] showing the corresponding morphological shapes of fragments (a) through (h) [lower right] as identified by the equations [upper right].

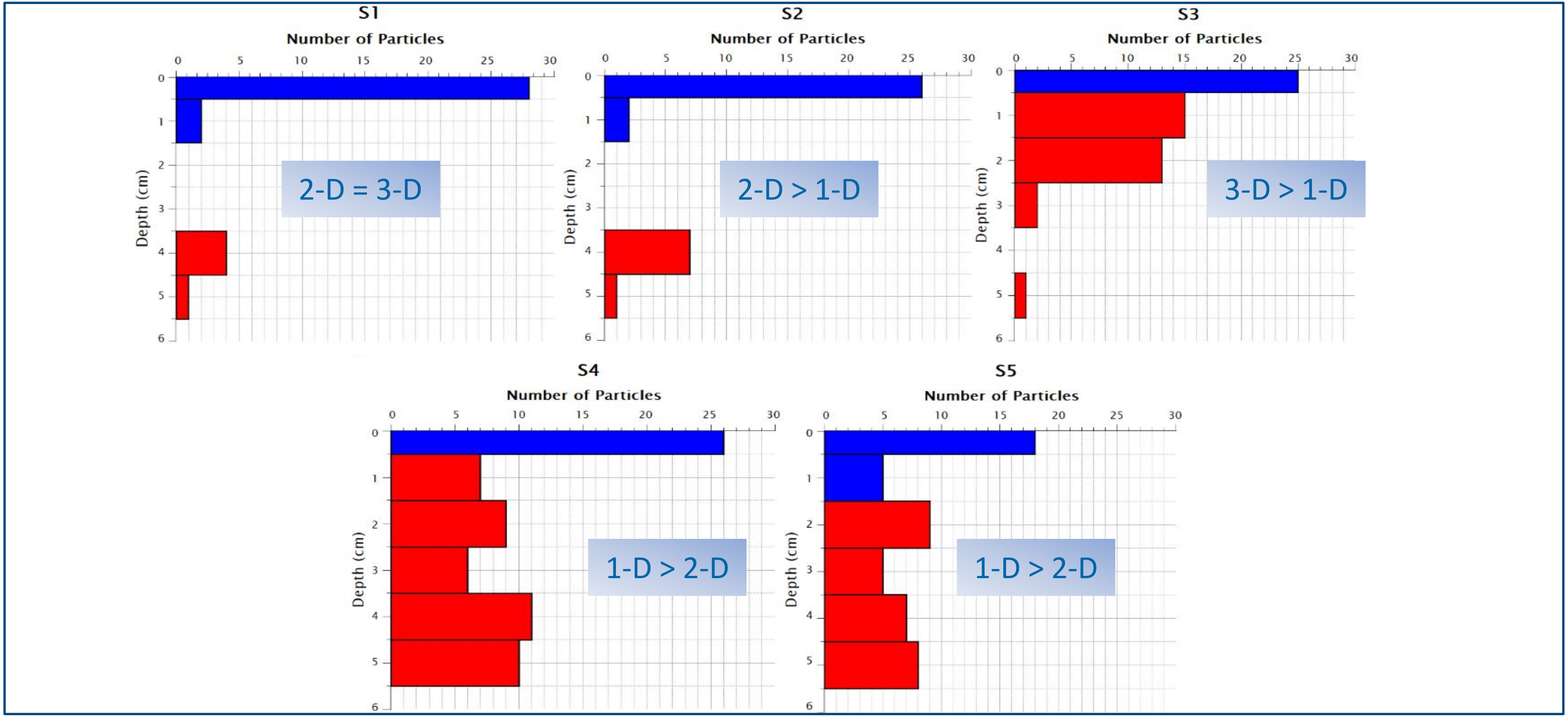
Soil Column Tests



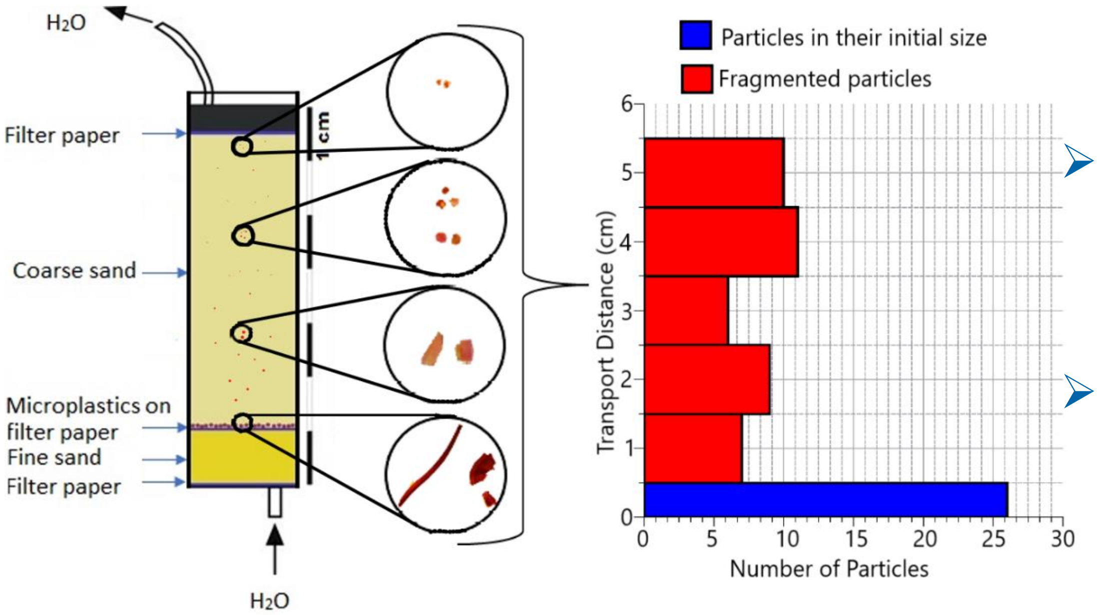
Length	5.5 cm
Coarse sand grain size	1.6 – 2.0 mm
Fine sand grain size	0.1 – 0.3 mm
Porosity of coarse sand	0.403
Porosity of fine sand	0.318
Flow rate	2.0 ml/min
Electrical conductivity of ultra pure water	0.055 µS/cm

Soil column setup [left], experimental parameters [right].

Retention profiles: 30 PVC particles



Conclusion



- Microplastic particles whose morphology was more 1-D fragmented the most which promoted migration.
- Fragment shape is the dominant factor in transportation.

Schematic representation of the soil column showing the distribution of particles of different sizes [left] and a representative retention profile [right].

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Effect of fragmentation on the transport of polyvinyl chloride and low-density polyethylene in saturated quartz sand

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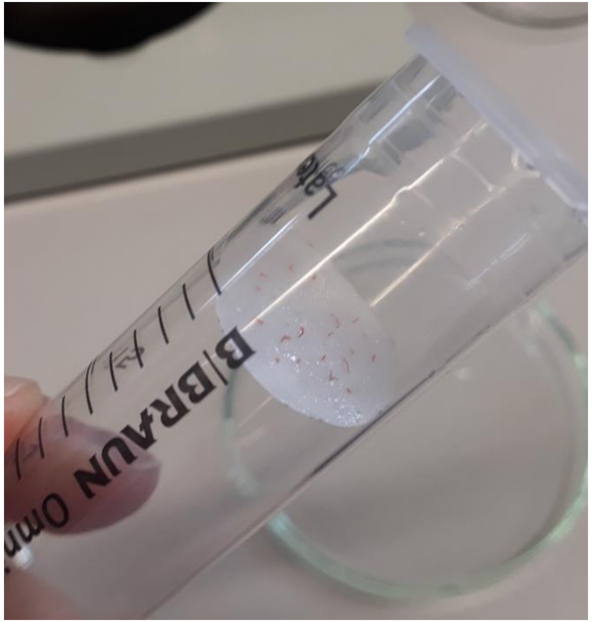
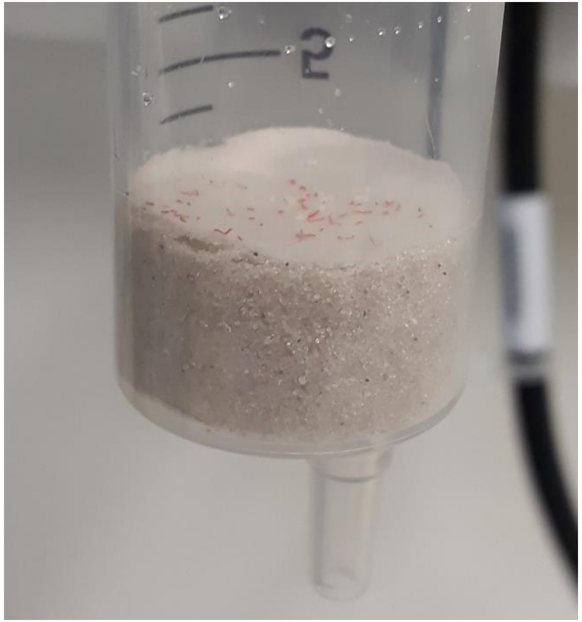
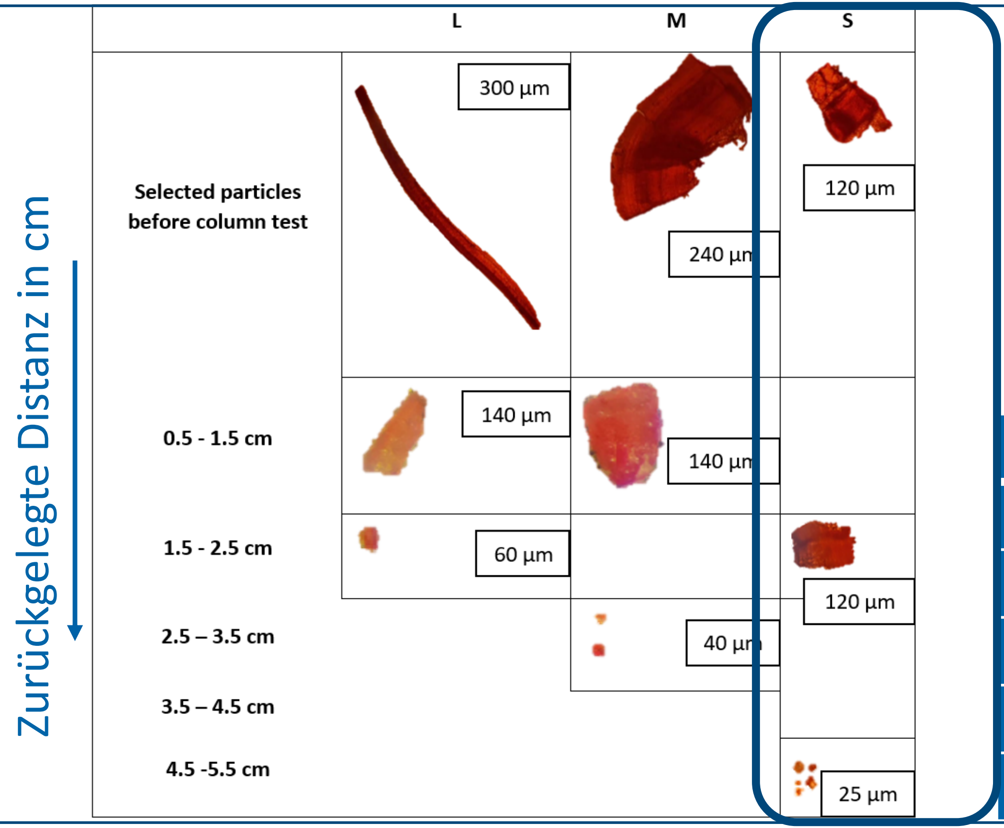
MPs in Säule platzieren





Untersuchung der Bewegung von PVC nach 4 Tagen bei einer Flussrate von 2 ml/min



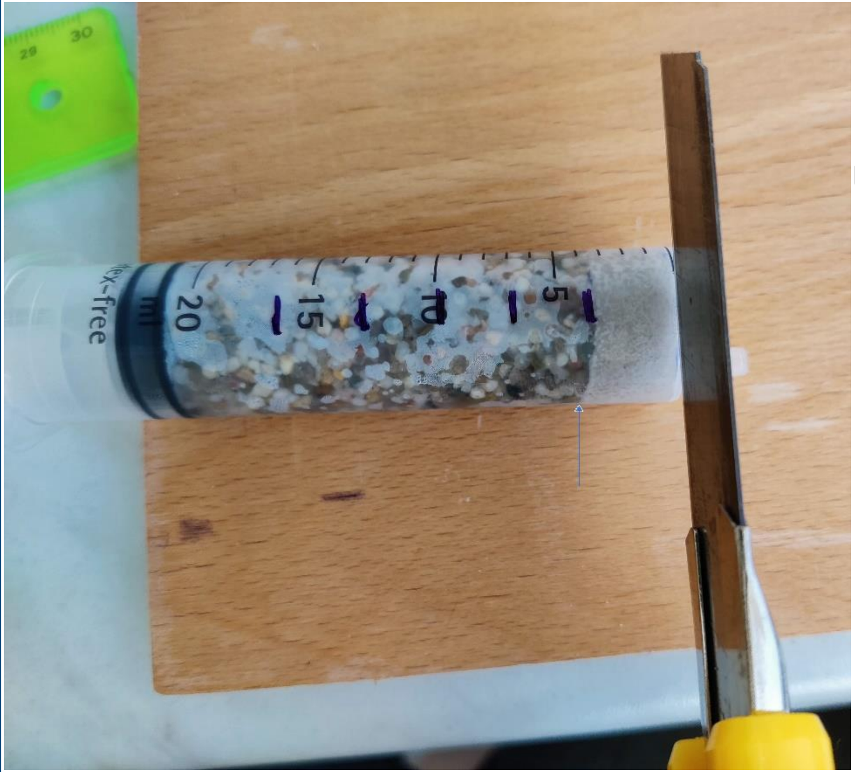
- L: $^{d_{MP}}/_{d_{sand}}$ = 0,10 – 0,19
- M: $^{d_{MP}}/_{d_{sand}}$ = 0,08 – 0,16
- S: $^{d_{MP}}/_{d_{sand}}$ = 0,06 – 0,13

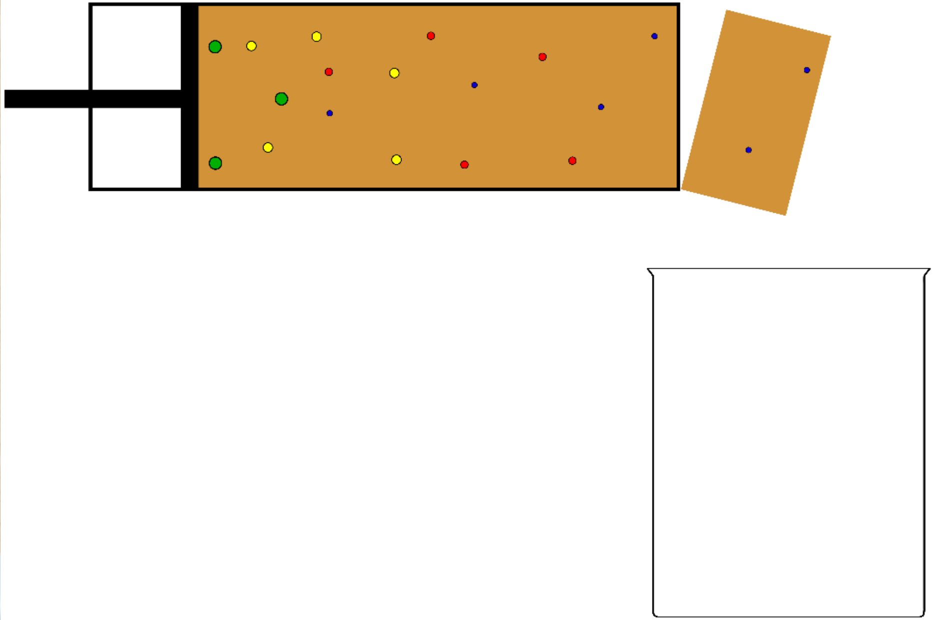
ungehinderte statische Perkolation bis **Infiltration in endlicher Tiefe**

*Fragmente

	L	M	S
Section 1	1*	6	5
Section 2	1*	1*	2
Section 3	0	2*	0
Section 4	0	0	7*
Section 5	0	0	5*

Segmentierung einer Probe aus der Säule





Erde aus der Säule vor dem Dekantieren mit $CaCl_2$ in Teflonbecher gegeben.