Quantifying the in-channel retention of cohesive sediments during controlled reservoir releases using FTIR-DRIFT spectrometry

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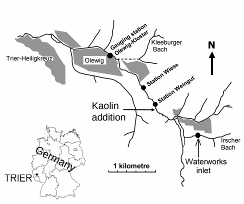
Introduction & Objectives



The investigated Olewiger Bach basin.

Cohesive sediments play an important role in river ecosystem quality both as pollutant carriers and as clogging material in river channels. However, experimental studies with cohesive sediments in natural river systems are rather scarce owing to the lack of convenient tracers and detection methods. As a result, current modelling approaches only insufficiently describe the fluvial transport dynamics and depositional behaviour of fine sediments.

The aims of our research are therefore

1. to investigate transport and retention dynamics of cohesive particles in a natural river system,
2. to evaluate the potential of FTIR-DRIFT spectrometry for quantifying mass transfer of fine particles.

Fine-grained particle transport during an artificial and a natural flood event.

Research approach

We adopted two strategies to specifically study cohesive sediment dynamics in natural systems under defined boundary conditions. First, artificial floods were generated by a waterworks in the Olewiger Bach basin (24 km²), a mid-mountain gravel bed river, in order to characterise the in-channel fine sediment dynamics on their own. The advantage of these artificial flood waves lies in the selective control on some governing processes by experimental design. Second, fine sediment transport and deposition during these controlled reservoir releases were analysed by introducing the clay mineral kaolinite as a fine particle tracer, whose concentration was measured by Fourier transform infrared spectroscopy (FTIR) in diffuse reflectance mode (DRIFT).

--- " Take home messages " ---

1. DRIFT - technique efficient measuring device for the quantification of kaolinite mass transfer as well as the characterisation of organic fines
2. High in-channel retention of cohesive fines even during floods owing to storage processes in channel periphery and dead zones and the hyporheic zone

Specific results

Lab experiments

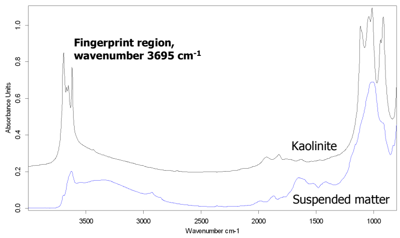


Fig. 1: Exemplary DRIFT spectra for kaolinite and an Olewiger Bach - suspended sediment.

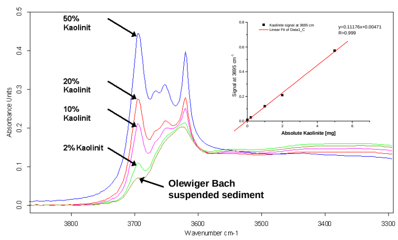


Fig. 2: Sensitivity and linearity of FTIR-DRIFT spectrometry for detecting the kaolinite tracer.

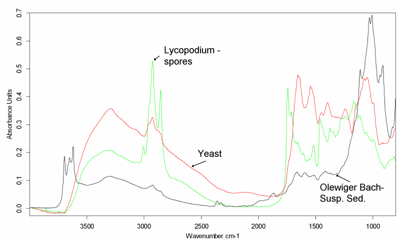


Fig. 3: FTIR-DRIFT as a means for organic fine particle characterisation.

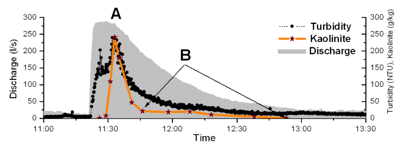
The Laboratory experiments

1. Kaolinite features a unique infrared fingerprint around wave number 3695 cm^{-1} (Fig. 1).
2. The measurements show a good sensitivity at 3695 cm^{-1} down to only 2 % kaolinite content and a linear signal with increasing amount of kaolinite (Fig. 2).
3. FTIR-DRIFT spectroscopy offers additional advantages such as the ability to assess organic fine-grained particles (Fig. 3), a high sample throughput and a very low amount of material needed for the analysis (only 10 mg).

The Field experiments & Future perspectives

1. During the selected artificial flood experiment (Fig. 4) two transport phases can be differentiated: *A:* the bulk of the tracer passes the measuring site featuring a substantial longitudinal dispersion, *B:* delayed transport of kaolinite with tracer concentrations still significantly higher than the background.
   The corresponding mass balance (Fig. 4) show that 42 % of the kaolinite passes the station in phase A, 2 percent in phase B. Thus, in spite of the very fine material and the non-stationary boundary conditions over 50 % of the tracer was retained over a flow length of only 570 m. This is equivalent to a loss rate of 14,7 g kaolinite per meter (Fig. 5).
2. Phase B is associated with an additional increase in dissolved organic carbon (DOC, not shown). The simultaneous rise of this tracer for interstitial water points at the role of the hyporheic zone in intermediate storage of kaolinite.
3. Within our multidisciplinary research group we will model the identified kaolinite retention using the new modular Stream - RIVer - Ecosystem package developed in the modelling platform "FEMME" (Flexible Environment for Mathematically Modelling the Environment, Fig. 6)

Field experiments



	Absolute amount of kaolinite kg	Relative amount %
Amount of released kaolinite	15.00	100.0
Transport in time segment A, Station Wiese	6.36	42.4
Transport in time segment B, Station Wiese	0.28	1.9
Sedimentation and retention respectively	8.36	55.7

Fig. 4: Cohesive sediment dynamics during an artificial flood, station Wiese, 570 m downstream the injection point, 26.07.2006.

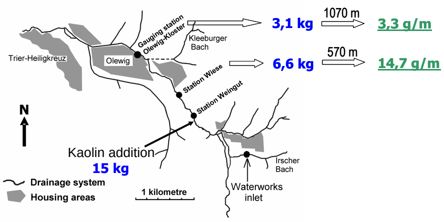


Fig. 5: Transported absolute kaolinite amounts per station (blue) and loss rates per meter (green) along the brook axis of the Olewiger Bach.

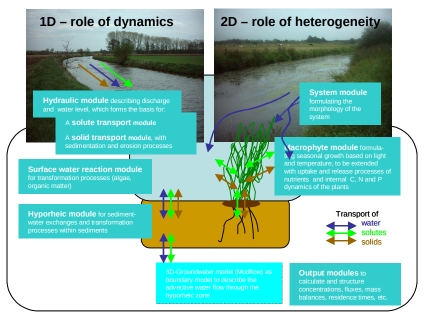


Fig. 6: Coupling of field experiment results with a new modelling approach based on a flexible sub module structure using the STRIVE package in FEMME.

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