Combining Two Filter Paper-Based Analytical Methods to Monitor Temporal Variations in Fluvial Suspended Solid Properties

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1. Research Objectives

- To develop an accurate, non-destructive, and cost-effective method of assessing the spatial and temporal dynamics of fluvial suspended solid properties under a range of in-stream hydrological conditions where there is an environmental requirement for high-resolution monitoring.
- To use this new method as a tool for fingerprinting sediment source areas under both low-flow and high-flow storm event conditions within the River Wensum catchment, UK.

2. Why is a new method required?

Many of the commonly used analytical techniques for assessing the properties of fluvial suspended solids (e.g. ICP, LOI) are neither cost-effective nor time-efficient, making them prohibitive to long-term high-resolution monitoring. We therefore propose a novel methodology utilising two types of spectroscopy which, when combined with automatic water samplers, can generate accurate, high-temporal resolution sediment property data, inexpensively and non-destructively, directly from sediment covered filter papers.

3. What did we do?

A dual X-ray fluorescence spectroscopy (XRFS)* and diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) approach was developed to estimate concentrations for a range of elements (Al, Ca, Ce, Fe, K, Mg, Mn, Na, P, Si, Ti) and compounds (organic carbon, Al dithionate, Al oxalate, Fe dithionate, Fe oxalate) within suspended solids trapped on quartz fibre filter papers at masses as low as 3 mg. Calibration models with small prediction errors were produced for all 16 elements and compounds, and corrections for sediment mass retention on each filter paper were derived.

*Cann JR, Winter CK. 1971. X-ray fluorescence analysis of suspended sediment in sea water. *Marine Geology* **11**: 33-37

4. Applying the technique

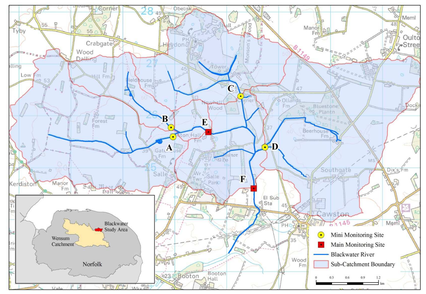
ISCO automatic samplers in bankside monitoring stations are remotely triggered to capture 1 litre stream water samples every 60-120 minutes during a storm, capturing the entire event in high-resolution.

Grab samples of stream water under low-flow conditions are collected weekly to fill in the gaps between storm events. Sediment from **field drains**, **road runoff**, **topsoils**, **road verges**, and **channel banks** are also sampled throughout the year as end members for the sediment mixing model.

All water samples are **vacuum filtered** through **quartz fibre filter (QFF) papers** to extract the suspended solids. Source area sediments are also transferred onto QFF papers after being **wet sieved** to **63 µm** to extract the fine silts and clays that become suspended in-stream. These filter papers are subsequently analysed by both **XRFS** and **DRIFTS** to determine the concentrations of major elements and compounds.

5. Study Area: The River Wensum DTC

The Demonstration Test Catchment (DTC) initiative is a joint UK based project between Defra, the Environment Agency, and the Welsh Assembly Government to evaluate the extent to which on-farm mitigation measures can cost-effectively reduce the impacts of diffuse agricultural pollution on river ecology whilst maintaining sustainable food production capacity. DTCs have been established in the Eden (Cumbria), the Avon (Hampshire), and the Wensum (Norfolk). Here, we focused on the Blackwater sub-catchment of the River Wensum - an internationally important chalk groundwater fed river with SSSI and European SAC status due to the diversity of its lowland calcareous flora and fauna. However, 99.4% of the stream habitat is in an unfavourable or declining state due to a combination of both nutrient enrichment and high sediment loads originating from the intensive arable agriculture that dominates this region. The River Blackwater therefore provides the perfect opportunity to demonstrate the effectiveness of this novel approach to high-resolution suspended sediment monitoring.



6. What happened during a succession of storm events?

Road Runoff

Median Concentrations:

Al:	11.76%	**Fe**:	6.86%
Ca:	6.55%	**Ti**:	0.59%
Mg:	1.14%	**Mn**:	0.17%
Na:	0.34%	**P**:	0.39%
Si:	12.13%	**K**:	2.07%
Ce:	91 ppm		

Eroding Channel Banks

Median Concentrations:

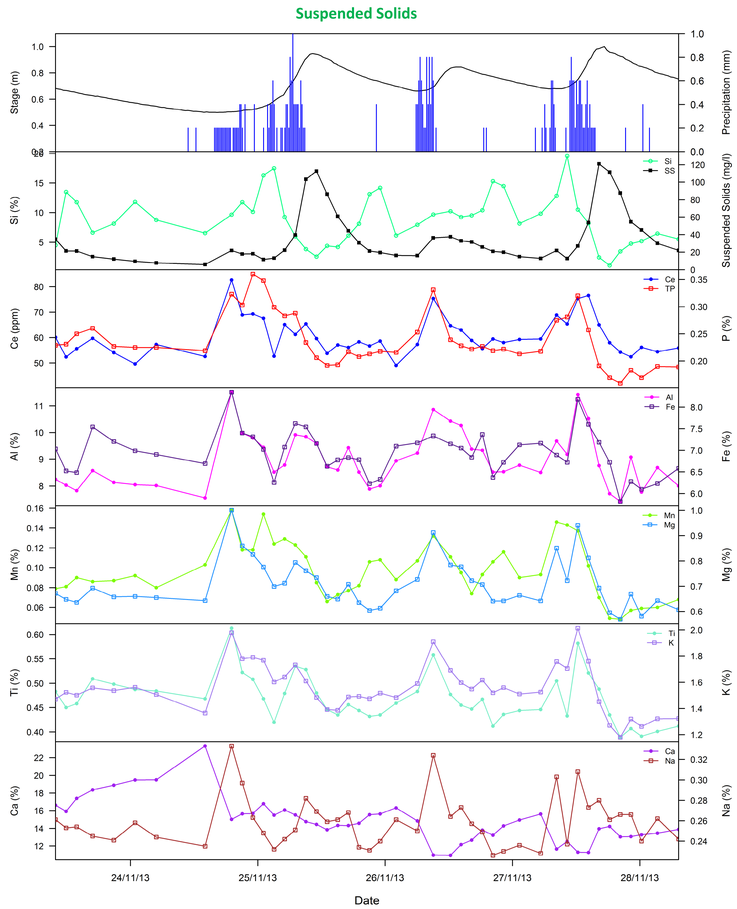
Al:	5.39%	**Fe**:	5.16%
Ca:	39.32%	**Ti**:	0.42%
Mg:	0.52%	**Mn**:	0.00%
Na:	0.22%	**P**:	0.05%
Si:	0.00%	**K**:	0.75%
Ce:	27 ppm		

Field Drains

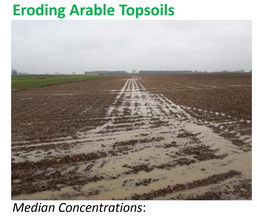
Median Concentrations:

Al:	7.77%	**Fe**:	8.24%
Ca:	12.83%	**Ti**:	0.39%
Mg:	0.56%	**Mn**:	0.11%
Na:	0.22%	**P**:	0.25%
Si:	11.82%	**K**:	1.30%
Ce:	51 ppm		

Suspended Solids



Eroding Arable Topsoils



Median Concentrations:

Al:	7.46%	**Fe**:	4.30%
Ca:	1.79%	**Ti**:	0.46%
Mg:	0.44%	**Mn**:	0.04%
Na:	0.52%	**P**:	0.15%
Si:	29.17%	**K**:	1.59%
Ce:	83 ppm		

Eroding Road Verges

Median Concentrations:

Al:	6.71%	**Fe**:	4.36%
Ca:	6.33%	**Ti**:	0.55%
Mg:	0.82%	**Mn**:	0.13%
Na:	0.49%	**P**:	0.20%
Si:	20.62%	**K**:	1.58%
Ce:	84 ppm		

Key Points

- Periods of intense and prolonged rainfall saturate the catchment leading to the generation of **surface runoff**.
- Suspended solid concentrations begin to rise within a few hours of the start of the precipitation event. Concentrations (mg/l) peak at **20 times** low flow concentrations shortly before maximum stage (m) is reached.
- Before the onset of the event, the suspended solids are characterised by **high calcium** contents and low concentrations of clay/silt associated elements, thus indicating **channel banks** are the main source of sediment during this time.
- Each rainfall event is then associated with a **peak** in **clay/silt** associated elements (Al, Fe, Mg, K, etc.) and Ce, which strongly suggests sediment input from surface sources. In particular, high concentrations of **Al**, **P,** and **Ti** indicate significant input from **road runoff**.
- As successive storm events pass through the catchment, **calcium** concentrations continue to **decline** as the relative importance of channel bank erosion to sediment supply is reduced with continued sediment input from surface sources.

Acknowledgements

This research is funded by a NERC BGS Case studentship