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 spectrometry (XRF) and diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) approach was developed to estimate concentrations for a range of elements (Al, Ca, Fe, K, Mg, Mn, Na, P, Si, Ti) and compounds (organics, calcium, Ca, Fe, K, Mg, Mn, Na, P, Si, Ti) in suspended solids trapped on quartz fibre filter papers at mean low 3 mg. Calibration models with small prediction errors were produced for 36 elements and compounds, and corrections for sediment mass retention on each filter paper were derived.

4. Applying the technique

ISCO automatic samplers in bankside monitoring stations are remotely triggered to capture the entire event in high-resolution. Each rainfall event is then associated with a high calcium content and low concentrations of clay/silt associated elements, which strongly suggests sediment input from surface sources. In particular, high concentrations of Al, Fe, Mg, and K, which suggest strong sediment input from surface sources. In particular, high concentrations of Al, Fe, Mg, and K, indicate significant input from road runoff.

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-stream 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 inland calcareous flora and fauna. However, 95-98% of the stream habitat is in an unsuitable 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

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.

Suspended Solids

Median Concentrations

All grab 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 XRF and DRIFTS to determine the concentrations of major elements and compounds.

Road Runoff

Eroding Arable Topsoils

Eroding Road Verges

Key Points

- Periods of intense and prolonged rainfall saturate the catchment leading to the generation of surface runoff.
- Suspended solids 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 Ca, which strongly suggests sediment input from surface sources. In particular, high concentrations of Al, Fe, Mg, and K, 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.

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