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Sediment traps as a tool for studying river suspended matter in water quality control and sediment management

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SUMMARY

The paper discusses the use of sediment traps to study suspended matter in rivers, which helps assess water quality and manage sediment. These passive samplers collect suspended particles over extended periods, allowing analysis of their composition, granulometry, and pollutant content. Applied to the Dnipro River, the study reveals valuable insights into sediment dynamics, pollutant distribution, and hydrological changes. The results contribute to hydrochemical monitoring and sediment management, particularly in the context of environmental impacts like the destruction of the Kakhovka Hydroelectric Power Plant dam.



Introduction

Suspended matter in water bodies, particularly particles suspended in the water column, acts as both an absorber and transporter of hazardous compounds, as well as a source of their secondary pollution in aquatic environments. As suspended particles travel through rivers, they undergo significant transformations, including aggregation or dissolution, as well as mechanical, chemical, and biological changes depending on external conditions (Walch et al., 2022; Satterberg et al., 2003). Additionally, changes in hydraulic flow characteristics—such as depth, current velocity, and bottom topography—continuously drive the exchange of settled particles between the sediment and suspension. The composition and concentration of suspended matter influence water intake quality, ecological, hydrological, and hydrobiological parameters of water bodies, and the condition and properties of bottom sediments (Borovec & Jan, 2018).

The study of the material composition of aquatic suspension makes it possible to determine the pathways of sediment supply to water bodies, the characteristics of surface runoff and coastal abrasion processes, the hydrobiological characteristics of aquatic areas, assess the impact of re-sedimentation mechanisms on the state of the hydrosphere, and analyze the seasonal and synoptic transformation of water masses in different sections of water bodies. Monitoring suspended matter, depending on the sampling methods used, can reflect both recent pollution and long-term environmental changes in river systems. The practice of studying sedimentogenesis characteristics in rivers over relatively long time periods to determine parameters such as the correlation with floods, periods of maximum winds, the impact of periodic pollution, and the seasons of planktonic organism development has necessitated the prolonged exposure of samplers at suspended matter collection points. This approach allows, first, the accumulation of a sufficient amount of natural material for comprehensive studies, and second, the averaging of target compound concentrations in sedimentary matter over specific periods to facilitate comparisons with long-term factors influencing sediment accumulation.

Methodology

A set of devices, classified as "passive samplers" according to ISO 5667-17:2008, has been developed by the team of authors and successfully used for an extended period. Essentially, these devices represent a type of sedimentation trap designed for sampling suspended sediments from vertical flows. Unlike short-term measurements of suspended matter content in water, which are typically conducted as part of routine monitoring by local authorities, the exposure duration of suspended matter traps is significantly longer and may last a month or more. The relatively calm accumulation of suspended particles in the trap is achieved through the geometry of its cylinders, which prevent the removal of the material entering them. The primary principle of sampling is based on the ability of the aquatic environment to homogenize suspended particles across the entire water area over discrete time periods. An increase in suspended matter in the flow, particularly during floods, occurs both in the main channel, where active horizontal movements of water masses prevail, and in hydrodynamically passive areas of the water body, where vertical movement of suspended particles and sedimentation processes dominate instead of channel transport. Under different natural hydrological conditions, deposited material in such areas may later be resuspended and removed from the bottom surface. However, the material accumulated in traps over a defined period remains, reflecting the sedimentation processes over the given time. It is important to note that the methodological approach has certain shortcomings, mainly due to the inability to objectively quantify the resuspension of suspended sediments. At the same time, comparing the masses of sediments deposited in the traps allows for an estimation of the relative dynamics of sediment accumulation over discrete exposure periods throughout an extended timeframe (Eisma, 2012).



These lightweight, compact, and reliable sediment traps generally meet the requirements for comprehensive sediment studies. In the basic design, the cylinder-accumulator of the sampler trap is made from 90 mm diameter plastic pipes (polypropylene sewage pipes "Ostendorf" with a diameter of 90 mm, with a length-to-inlet diameter ratio of 1/3). The design of the traps includes a removable component that simultaneously serves as a container for sample collection, transportation, and initial examination in laboratory conditions. The material from which the sampler is made is chemically inert, easy to clean, and transparent for visual evaluation of the sample. This is a standard 0.5-liter glass jar, the versatility and low cost of which are prerequisites for successful application. The transparent glass allows for visual observation of the sediment distribution, and the light weight of such a sampling device enables its installation and removal in various locations (Fig. 1).



Figure 1 General view of the traps with a pin-type fixer at the bottom and the procedure for replacing removable sample collection components.

The design involves the use of three sedimentation cylinders in a single aggregation – a sedimentation trap, which, according to the task conditions, can be suspended in the water column on ropes or fixed to the bottom with a pin. Primarily, such samplers are deployed, as already mentioned, in hydrodynamically passive zones of water areas, and the long-term settling of substances in them allows for the accumulation of the necessary amount of material for determining:

- The composition of river suspended matter (Figures 2 and 3) at different time periods, particularly the distribution of mineral and organic/organogenic components, which will indicate, among other things, the sources of suspended particles formation and changes in their contribution over extended time periods (seasonality, annual cycles);
- Granulometric and chemical component composition of the suspended matter;
- Relative intensity of its vertical flows over time (monthly changes), as well as the concentrations and volumes of various pollutants carried on its particles or within its composition;
- Periods of maximum organic component content, particularly phytoplankton shell fragments within the suspended matter, and their species composition.



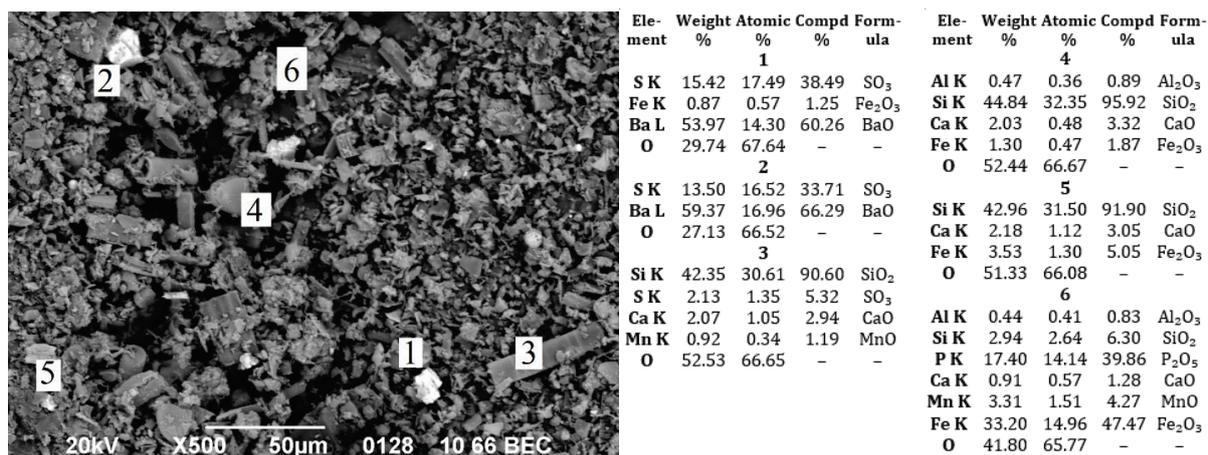


Figure 2 Electron microscope image of the component composition of the suspended matter sample from the Dnipro River within the city of Zaporizhzhia, collected by sedimentation traps (sampling period: second half of March – first half of April 2016). It is specifically noted that, while silica predominates in the sample overall, it is mostly represented by the organic component. The elemental composition of individual particles of aleurite size: 1, 2 - Barium sulfate (barite BaSO₄), 3, 4, 5 - Silicate shells and detritus of planktonic organisms, 6 - Fragments of iron oxide.

Conclusion

Simultaneous monthly determination of the complex of the listed indicators over a long period (Figure 3), and their correlation with the hydrological characteristics of the river (measurements of turbidity and discharge) allows for identifying a range of interdependencies in the distribution of suspended matter components, the presence of pollutants, and natural hydrological conditions. The results of such studies, particularly the determination of the characteristics of intra-annual dynamics of suspended matter, changes in its component composition throughout the year, the intensity of sedimentation processes, and the distribution of various pollutants, including heavy metals and pesticides, can become an important component of existing hydrochemical monitoring systems for river basins and the justification of sediment management measures. For a long time, the authors' team has been conducting such monitoring of suspended matter on the Dnipro River within the city of Zaporizhzhia (Nasiedkin et al., 2022), and similar studies have also been initiated in the lower course of the Danube (Vilkovo). One of the applied aspects of such studies is, among other things, the assessment of the damage caused to the lower Dnipro by the destruction of the Kakhovka Hydroelectric Power Plant dam by Russian occupiers.

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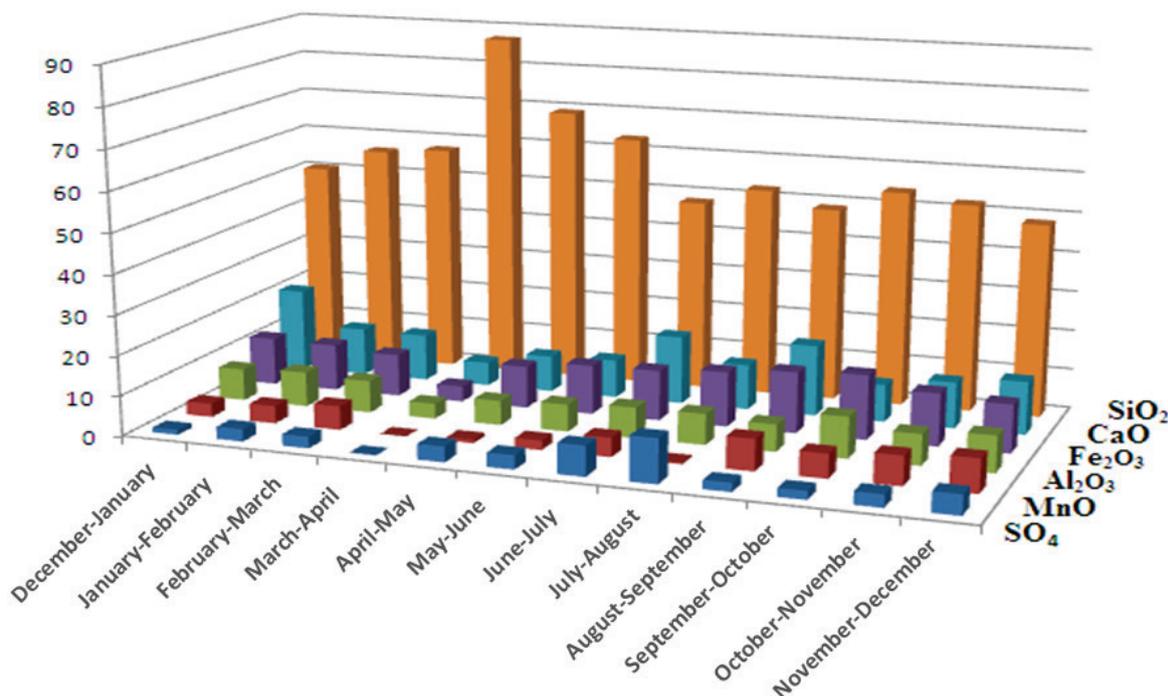


Figure 3 Monthly average distribution of the main components of river suspended matter (%), collected by sedimentation traps within the study area of the Dnipro River in the city of Zaporizhzhia, integrated indicator for the years 2015-2019.

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