FIELD-VALIDATED DNA TRACER CAPTURE SYSTEM FOR SUSTAINABLE GROUNDWATER AND SURFACE WATER MONITORING

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Abstract - The study of water circulation and solute transport in natural and agricultural environments is fundamental for supporting sustainable water management strategies and improving the protection of groundwater resources. In recent years, synthetic DNA tracers have gained attention as innovative tools for hydrological investigations due to their high specificity, low environmental impact, and capability to distinguish complex flow pathways.

This work presents the development and field validation of a passive device designed to recover biotinylated DNA tracers from surface water and groundwater systems. The trapping system consists of a hybrid chamber containing streptavidin-coated magnetic beads immobilized within permeable agarose hydrogel structures. This configuration allows selective binding of DNA tracers while enabling water to freely circulate through the device during deployment.

Experimental activities were conducted both under controlled laboratory conditions using column filtration tests and in a real environmental setting through tracer injections performed in a natural stream. The results showed that the temporal evolution of DNA tracer signals obtained from the capture devices was comparable to the breakthrough behaviour observed for traditional tracers such as salts and fluorescent dyes. Moreover, the passive trapping approach provided integrated information on tracer transport, allowing improved detection of delayed flow components and heterogeneous transport processes.

Quantitative PCR analysis confirmed the high sensitivity and reliability of tracer detection across a wide range of concentrations. The proposed methodology represents a practical and environmentally safe solution for hydrological monitoring, with potential applications in irrigation planning, assessment of groundwater vulnerability, and evaluation of contaminant migration in agro-environmental systems.

A patent application related to the DNA capture device is currently under preparation. The integration of molecular tracer techniques with simple field-deployable sampling systems offers promising opportunities for advancing environmental diagnostics and sustainable water resource management.