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From Low-Cost Prototypes to a Validated Field System: Evaporation-Free Automatic Rain Sampling for Stable Water Isotopes

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The rapid development of laser spectrometry for water isotope analysis has enabled high-frequency investigation of hydrological processes at substantially reduced analytical cost. However, the reliability of such datasets critically depends on robust sampling systems that prevent evaporative fractionation during storage—particularly in remote or logistically challenging environments.

Building on previous work with low-cost and do-it-yourself (DIY) sampling methods for precipitation, surface water, and groundwater, we introduce the development and validation of a new field-ready automatic rainwater sampler designed specifically for stable isotope applications. Within a UFZ–MAXX TransMarket collaboration, a portable, battery-operated rainfall sampler (MAXX P 6 L-Rain) was developed to ensure evaporation-proof storage of collected samples in sealed bags. The system operates autonomously and activates only during rainfall events. Rainwater is automatically distributed into individual storage bags, minimizing sample handling and reducing the risk of post-sampling isotopic alteration. Particular emphasis was placed on preventing evaporative enrichment and ensuring sample integrity during storage under variable environmental conditions.

Controlled laboratory experiments were conducted to quantify potential evaporative fractionation and to evaluate the integrity of the complete sampling system [1]. Results demonstrate effective prevention of isotopic shifts in δ^2H-H_2O and $\delta^{18}O$-H_2O during storage, confirming the suitability of sealed bag storage for isotope hydrology applications. Further planned laboratory tests and field applications in 2026 will confirm the system's robustness in outdoor conditions. Isotopic compositions obtained from automated sampling show strong agreement with reference manual sampling, indicating reliable performance during natural rainfall events.

The portability, low power demand, and autonomous operation of the system make it particularly suitable for remote sites, arid regions, and areas with limited infrastructure. By enabling reliable high-resolution rainfall isotope monitoring without intensive field maintenance, the system facilitates event-scale process studies and long-term isotope observations. This development demonstrates how targeted engineering solutions combined with isotope hydrology expertise can expand access to high-frequency isotope monitoring and strengthen hydrological research in both well-instrumented and data-scarce regions.

[1] Mueller, C., T.G. Pekarev, and K. Knoeller, *Technical note: Efficiency of various evaporation barriers for use in automated water samplers for subsequent water isotope analysis.* EGUsphere, 2025. **2025**: p. 1-18.