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Urban River Contamination Case Study: Spatial-Temporal Dynamics of Emerging Contaminants in the Fervença River (Bragança, Portugal)

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INTRODUCTION & AIM

Urban rivers are among the most vulnerable freshwater systems, as they integrate multiple anthropogenic pressures within relatively small catchments. Wastewater discharges, stormwater runoff, and diffuse urban inputs contribute to the continuous release of emerging contaminants (ECs), particularly pharmaceutical residues, into aquatic environments.

Although conventional wastewater treatment plants (WWTPs) significantly reduce pollutant loads, many pharmaceuticals are only partially removed and may persist in receiving waters. In addition to the water column, sediments can act as secondary contamination reservoirs, influencing long-term environmental exposure and ecological risk.

Despite growing concern, spatial-temporal assessments of emerging contaminants in small urban rivers remain limited, particularly when integrating both water and sediment compartments.

Understanding these dynamics is essential for evaluating wastewater footprints and supporting evidence-based management strategies.

This study aims to evaluate the spatial and temporal dynamics of pharmaceutical emerging contaminants in the Fervença River (Bragança, NE Portugal), with special focus on:

- The influence of the municipal WWTP discharge
- Differences between upstream, urban, and downstream sections
- Partitioning behavior between water and sediments
- Temporal variability between 2018 and 2024

By integrating multi-compartment monitoring, this work provides insight into contamination patterns and the vulnerability of small urban river systems to wastewater-related pressures.

METHOD

Study Design

- **Case study**: **(Fig. 01 & 02)**
  Fervença River (Bragança, NE Portugal)
- **Four sampling campaigns:**
  - ❑ 2018 (baseline dataset)
  - ❑ March, May and September 2024
- **Three sampling points:**
  - ❑ Upstream (rural area) **(F1)**
  - ❑ Urban section **(F2)**
  - ❑ Downstream of WWTP **(F3)**

Figure 01: Bragança ubication.

Sampling and Analysis

- Water and surface sediment samples collected at river sites
- Target analysis of selected pharmaceutical compounds
- Quantification by HPLC-MS/MS
- In situ measurement of physicochemical parameters (e.g., temperature, pH, conductivity)

Data Treatment

- Spatial comparison between river sections
- Assessment of WWTP influence
- Temporal comparison (2018 vs 2024 campaigns)
- Evaluation of distribution patterns between water and sediments

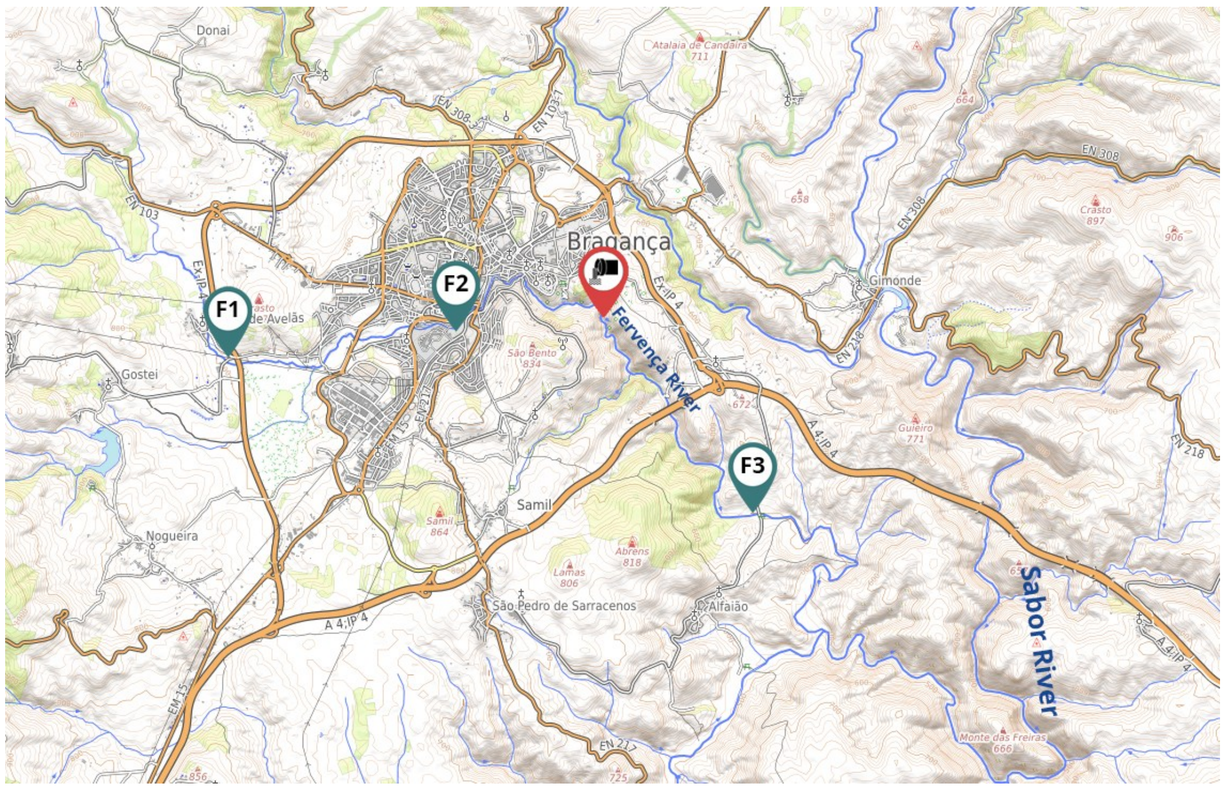

Figure 02: Map of sampling points and WWTP ubication (red).

RESULTS & DISCUSSION

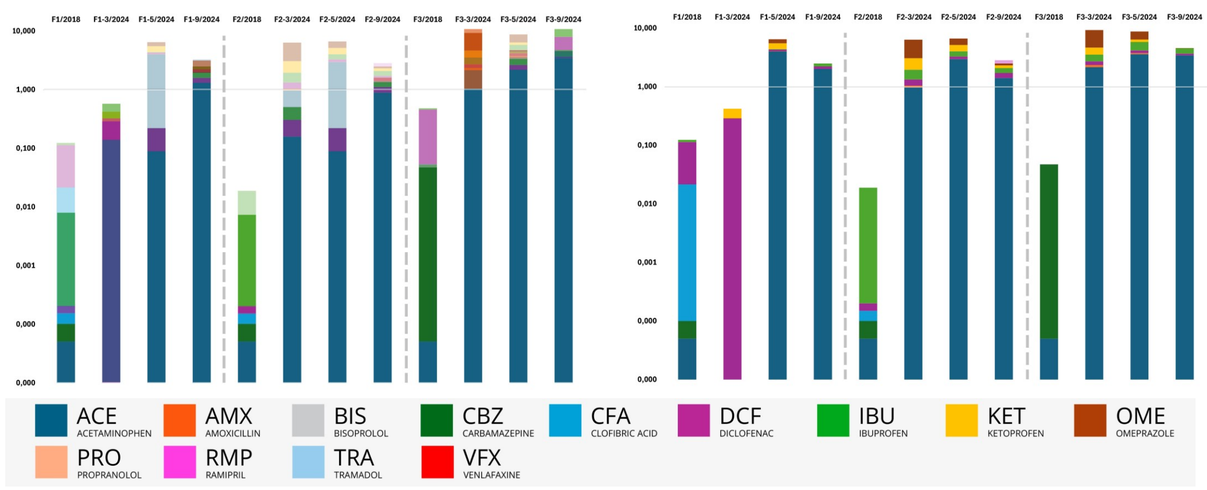

Figure 03: Cumulative concentrations of detected pharmaceuticals in water (log scale).

Figure 04: Cumulative concentrations of detected pharmaceuticals in sediments (log scale).

A total of eleven pharmaceutical compounds were detected in surface water samples throughout the study period, confirming the continuous presence of emerging contaminants in the river system.

Among them, acetaminophen was consistently the dominant compound in terms of concentration across sites and campaigns. Other frequently contributing substances included ibuprofen, diclofenac and amoxicillin, which substantially influenced cumulative loads, particularly in the downstream section **(Fig. 03).**

Spatially, cumulative concentrations showed a heterogeneous pattern. While the upstream site (F1) exhibited measurable pharmaceutical presence, the downstream site (F3) consistently presented the highest concentrations during the 2024 campaigns, highlighting the influence of treated wastewater discharge. The urban site (F2) showed intermediate values, reflecting mixed urban inputs and hydrological variability.

Higher concentrations in 2024 suggest increased urban pressure compared to 2018.

Overall, water results demonstrate a clear anthropogenic pressure.

Sediment analysis showed the presence of ten pharmaceutical compounds, indicating that benthic compartments act as sinks for emerging contaminants.

As observed in water, acetaminophen contributed substantially to cumulative concentrations; however, other compounds such as diclofenac, carbamazepine, and omeprazole showed relatively greater relevance in sediments compared to the water column, suggesting compound-specific partitioning behavior **(Fig. 04).**

The downstream site (F3) exhibited the highest cumulative sediment concentrations in the 2024 campaigns, supporting the role of WWTP effluent as a continuous source of contaminants that may accumulate over time. The upstream site (F1) displayed episodic detections, while the urban site (F2) generally showed lower sediment accumulation, possibly influenced by hydrodynamic conditions and sediment characteristics.

These findings emphasize the importance of sediment monitoring to capture long-term contaminant persistence that may not be fully reflected in water samples alone.

A logarithmic scale was applied to allow comparison of compounds spanning several orders of magnitude

CONCLUSION

This study reveals a clear wastewater signature in the Fervença River.

Pharmaceutical residues are not fully removed during treatment. They are discharged into the river, transported downstream, and partially transferred to sediments, where they can persist beyond the immediate water signal **(Fig. 05).**

Even upstream sections are not exempt from contamination, reflecting diffuse anthropogenic pressures. Downstream areas show sustained contaminant loads, confirming the influence of treated effluent as a continuous source.

Small urban rivers function as sensitive receivers of chemical pressure, integrating diffuse inputs, treatment inefficiencies, and hydrological processes.

Understanding this dynamics, from urban use to sediment accumulation, is important for designing effective mitigation strategies and protecting freshwater ecosystems.

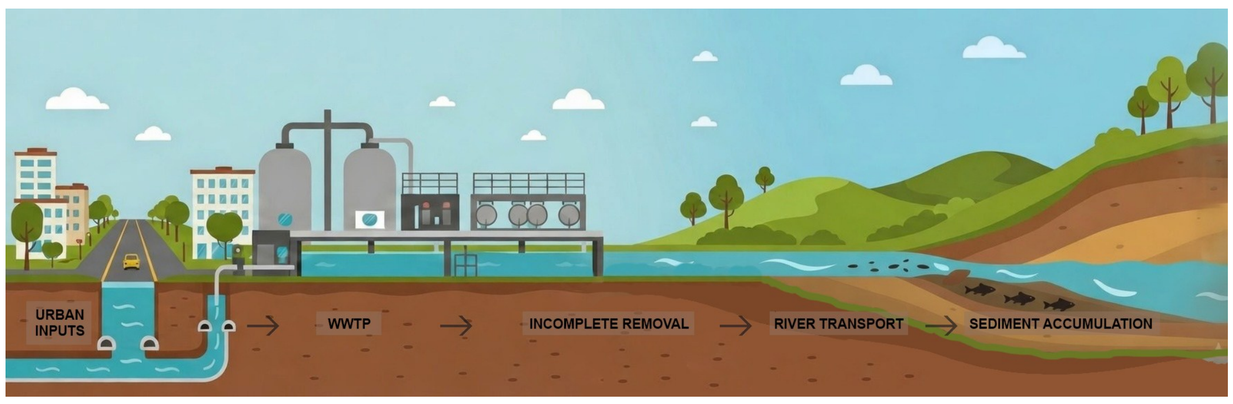

Figure 05: Conceptual representation of the urban wastewater footprint in the Fervença River. (Concept design created with AI,and finished in PS.)