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Patterns of Community-Level Drug Consumption from Real-Time Wastewater Monitoring

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Wastewater contains a complex and dynamic mixture of chemicals that reflects collective human activity. Among these are residues of illicit drugs, pharmaceuticals, and lifestyle-related compounds. Analysis of such markers in sewage can provide anonymous insights into community-level consumption patterns, an approach commonly referred to as wastewater-based epidemiology (WBE). In WBE, chemical analyses are typically performed on 24-hour composite samples collected at wastewater treatment plant influents. While this enables the determination of daily loads, the composite nature inherently averages out intraday patterns that can provide important information on the dynamics and sources of specific chemicals in wastewater. Capturing such intraday dynamics is currently limited by the substantial manual effort required for conventional high-frequency sampling and analytical workflows.

In this study, we tried to overcome this limitation by performing automated real-time on-site analyses using a transportable liquid chromatography-mass spectrometry (LC-MS) platform (MS²Field) developed at Eawag (Fig. 1).

At the influent of the wastewater treatment plant in Zurich, serving approximately 471,000 inhabitants, samples were analysed every 36 minutes over a 60 day period from July to September 2023 (1,909 measurements) (Fig. 2).

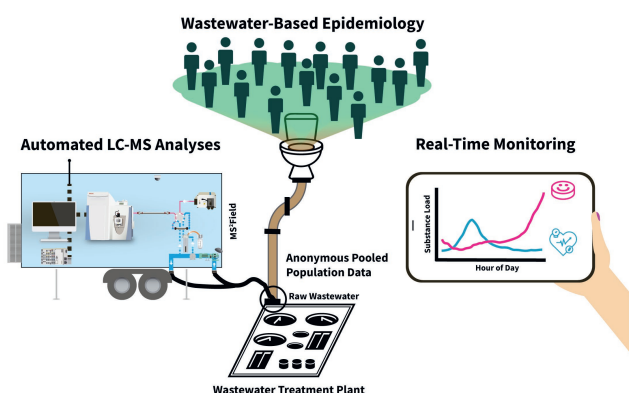


Fig. 1. Graphical summary of automated liquid chromatography-mass spectrometry (LC-MS) measurements and real-time data provision for wastewater-based epidemiology using the transportable MS²Field platform.

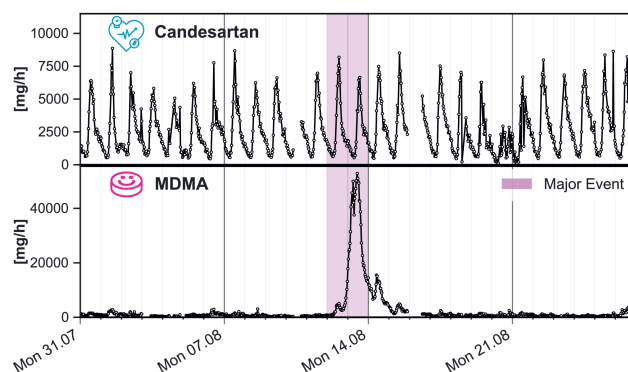


Fig. 2. Time-resolved loads of substances for (i) candesartan, a widely prescribed antihypertensive exhibiting consistent intraday patterns, and (ii) MDMA, characterized by pronounced peaks during large-scale events. The period corresponding to a major public event is indicated by pink shading.

The resulting high-frequency time series revealed substance-specific intraday load patterns with distinct temporal profiles and weekday effects. For most substances, the highest concentrations and loads were observed in the morning hours, presumably linked to the first morning void. This morning peak shifted approximately one hour later on weekends compared to workdays. Population biomarkers such as the caffeine metabolite paraxanthine and the artificial sweetener acesulfame showed comparatively stable loads during daytime hours, presumably reflecting continuous consumption and excretion, and likely also contributions from commuting populations. In contrast, the antihypertensive drug candesartan, for example, showed a single morning peak followed by a steady decline.

For illicit drugs, generally higher loads were observed on weekends and marked rises occurred during major public events. Such event-driven increases were particularly pronounced for MDMA, with daily loads rising by up to a factor of 20 compared to typical weekend levels.

For WBE specifically, high-frequency measurements provide a detailed view of substance-specific wastewater dynamics, which is useful for understanding and validating the approach across the full chain from consumption and excretion, through in-sewer transport, to load calculations at the treatment plant, and can offer insights into potential sources, including disposal or manufacturing activities.^[1]

The real-time nature of the data further represents a step towards improved wastewater-based public health preparedness.

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[1] S. Baumgartner, E. Ceppi, P. Longrée, M. Salvisberg, H. Singer, C. Ort, *Water Res.* **2025**, 287, 124337, <https://doi.org/10.1016/j.watres.2025.124337>.