





































Original Research

Bridging the gap between research and decision making: A European survey to enhance cooperation in wastewater-based epidemiology (WBE) for illicit drugs

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ABSTRACT

Objectives: Illicit drug use presents a significant challenge to global health and public safety, requiring innovative and effective monitoring strategies. This study aimed to evaluate the current landscape of wastewater-based epidemiology (WBE) for monitoring illicit drugs in Europe, focusing on collaboration, current practices, and barriers, while identifying opportunities for improvement.

Study design: Cross-sectional survey-based study.

Methods: Coordinated by the Sewage Analysis CORE Group Europe (SCORE) and the European Union Drugs Agency (EUDA), two surveys were conducted in 2023 targeting researchers and stakeholders using WBE for illicit drugs. Data were analysed to identify trends, gaps, and opportunities for improving WBE implementation.

Results: The findings indicate a robust research infrastructure and diverse analytical methods among European institutions. Two-thirds of the participating countries reported using WBE data to inform policy. However, challenges persist, particularly in securing funding and coordination, as well as generating national estimates from multiple locations and addressing specific local policy needs.

Conclusions: WBE has proven to be a valuable tool for monitoring illicit drug trends and informing drug policies. To unlock its full potential, sustained funding, methodological standardization, and enhanced cooperation are essential. This study provides critical insights into the European WBE landscape, offering a roadmap for strengthening the integration of actionable WBE data into public health and policy frameworks.

1. Introduction

Illicit drug use contributes substantially to the global burden of disease, morbidity, and organised crime.¹ The United Nations Office on Drugs and Crime (UNODC) Drug Report 2024 highlights a growing global drug crisis, driven by the emergence of new synthetic opioids and record levels of drug production and use. With 292 million people using drugs in 2022, a 20 % increase over the past decade, drug-related harms, including rising overdose deaths and drug use disorders, continue to escalate.² Therefore, strategic response using evidence-based monitoring data is of paramount importance in shaping drug policy decisions, understanding drug use patterns and mitigating the consequences of unregulated drug markets.

Traditional drug monitoring methods relying on established data sources and community-based reporting systems provide valuable insights into drug use trends. However, often fall short in capturing the real-time dynamics of drug consumption. In response to the growing number of people who use drugs globally, innovative techniques are essential. Wastewater-based epidemiology (WBE) has emerged as a powerful tool that provides timely and accurate data on temporal trends of drug use at the population level, offering a unique and comprehensive perspective to support public health decision making.³ This approach not only enhances our understanding of drug use patterns but also supports the development of targeted interventions and provides evidence for harm reduction policies.⁴ Additionally, WBE can support public health decision makers as an early warning tool for the identification of new emerging substances such as nitazene analogues, a group of very potent synthetic opioids that have emerged in several high-income countries and have recently been detected in wastewater.⁵

WBE is rapidly gaining traction globally. However, its policy value has not yet been broadly established for decision making. Increased cooperation between scientists and interdisciplinary actors, such as decision makers, is essential.^{6–9} Yet, in a few countries such as Australia,¹⁰ Finland¹¹ or New Zealand¹² cooperation between institutions performing WBE and public health or law enforcement authorities has already become common practice. The Sewage Analysis CORE Group Europe (SCORE) network in collaboration with the European Union Drugs Agency (EUDA; formerly called European Monitoring Centre for Drugs and Drug Addiction, or EMCDDA) has been coordinating the most comprehensive monitoring of illicit drug use through WBE since 2011.^{3,13} The results from this global collaborative exercise are used and published by the EUDA¹⁴ and the United Nations Office on Drugs and Crime (UNODC).¹⁵

The SCORE network was established in 2010 with the aim of standardizing the wastewater analysis approach and coordinating international studies through the creation of a consensus protocol for sampling, analysing, and reporting. This study began with 12 laboratories reporting wastewater data from 21 wastewater treatment plants (WWTPs) and has since expanded to include 41 laboratories and 137 WWTPs, according to the most recent metrics from the study conducted in 2023.¹⁴ From 2025 onward, the SCORE network expects to dedicate more efforts to improve and facilitate the cooperation and coordination among the research community and stakeholders developing and adopting WBE tools. To achieve that, two different surveys for researchers and stakeholders at European level were launched in 2023.

The objective of the survey and this article was to collect the baseline information on the experience of researchers and stakeholders performing WBE for illicit drugs to outline the current situation and identify

gaps and future opportunities to improve 1) collaboration and knowledge sharing across Europe and neighbouring countries, and 2) national coordination among the research community and stakeholders (government organisations, private sector, and research funders) using WBE for illicit drugs monitoring.

2. Methods

2.1. Survey design and eligibility

The survey was created using the EU-Survey online system hosted at the European Commission's Department for digital services (DG DIGIT). The SCORE-core group, the main group of scientists coordinating the SCORE network, designed two separate questionnaires for 1) expert researchers and 2) stakeholders in the field of WBE for illicit drugs in Europe. The survey was self-completed online by participants using the online survey system. The two surveys were performed separately.

The questionnaire designed for the research community, referred to in the article as "SCORE", covered different domains: infrastructure and funding, research and innovation, and data utility. Participants' recruitment occurred through the SCORE network mailing list, which comprises an international group of 224 international researchers that have been working on WBE and engaging with the SCORE network since 2011. The questionnaire distributed among the research institutions was conducted between July 27, 2023 and September 8, 2023.

The questionnaire designed for stakeholders, referred to in the article as "Reitox", was focused on the understanding of WBE, collaboration and main barriers, data utility for decision makers and sustainability. Participant recruitment occurred through the EUDA's Reitox network of national focal points (NFP) mailing list. These are the designated national institutions or agencies responsible for the data collection and reporting on drugs and drug addiction that support the development of European drug action plans and strategy.¹⁶ The questionnaire for stakeholders was conducted between September 1, 2023, and October 31, 2023. Responses from the NFPs were anonymized throughout the manuscript after being requested. Results were downloaded from the EU-Survey platform and described systematically. The surveys used in this study are available in Supplementary material.

3. Results

3.1. Participants

Of the 224 contacts (including multiple people and research groups per country) from the SCORE mailing list, 34 delivered an electronic response to the survey. From the 34, two were excluded for duplication and 5 for not being a European or bordering country (Canada, New Zealand, and United States of America), leaving a total of 27 data entries representing 20 countries. Countries submitting data were Austria, Belgium, Cyprus, France, Germany, Greece, Iceland, Italy, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye, and the United Kingdom. Most of the organisations were research institutions ($n = 23$) followed by three governmental agencies and one private company.

The EUDA invited all Reitox NFP members to participate in the electronic survey using their mailing list of 29 organisations, from which 14 submitted responses using the EU-Survey platform. One data entry was excluded for duplication. Countries submitting data were Austria, Croatia, Cyprus, Czechia, Finland, France, Hungary, Italy, Lithuania, Luxembourg, the Netherlands, Norway, Slovenia and Sweden. NFPs conducting the survey were from organisations representing governmental agencies ($n = 10$), research institutions ($n = 6$) and private companies ($n = 1$), Fig. 1.

3.2. Part 1: Results from SCORE network

3.2.1. Current WBE national infrastructure, substances, and funding

Most SCORE survey participants (93 %, $n = 25$) reported to have a dedicated research infrastructure with access to wastewater samples. They highlighted strong collaboration with WWTP operators, well-trained research groups, and validated methods using liquid chromatography coupled to mass spectrometry (LC-MS/MS) or high-resolution mass spectrometry (LC-HRMS) and gas chromatography coupled to mass spectrometry (GC-MS). Of the 25 groups with infrastructure, three confirmed to have access to wastewater samples, but lacked operational analytical methods.

Access to wastewater samples and population estimates varied. Greece had the highest coverage (78 % of the population), followed by Cyprus (60 %), Austria and Türkiye (56 %), France (47 %), and Belgium (43 %). Lithuania, Slovenia, Luxembourg, Iceland, Norway, Spain,

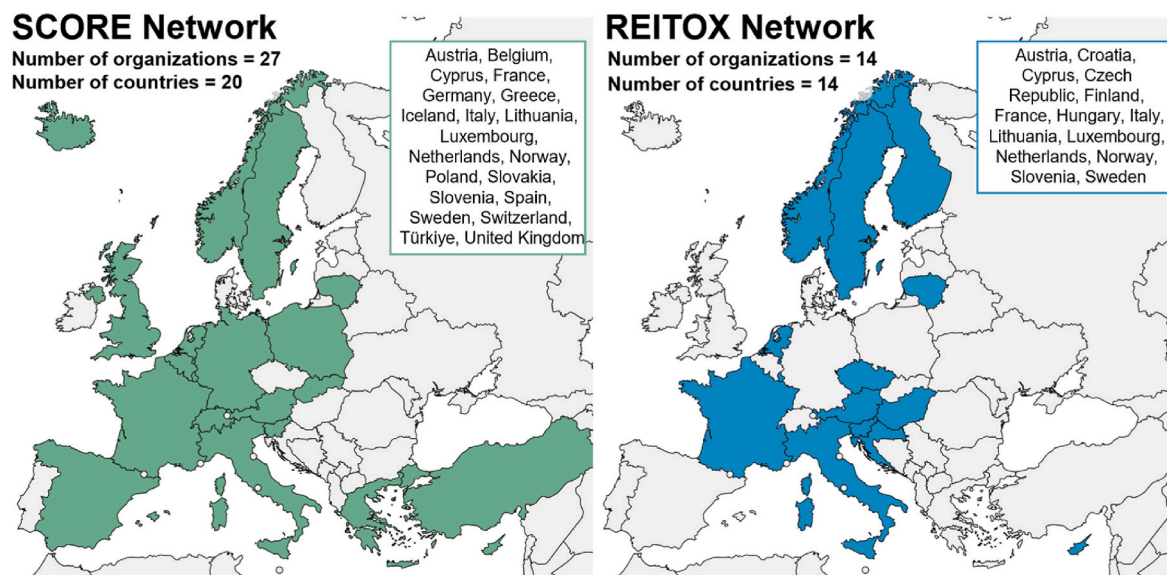


Fig. 1. Map of the 20 countries that responded to the survey conducted among researchers in the SCORE Network participating in WBE (left). Map of the 14 countries that responded to the survey sent to the 29 national focal points of the Reitox Network (right).

Switzerland, and the UK reported coverage between 20 and 40 %, while Germany, Italy, the Netherlands, Poland, Slovakia, and Sweden covered less than 20 % (Fig. 2, left). Spain’s participants noted access to nationwide samples through the ESAR-NET network.

Most participants had validated methods for reporting benzoyllecgonine (85 %, n = 23), amphetamine (89 %, n = 24), methamphetamine (89 %, n = 24), and MDMA (85 %, n = 23), substances included in EUDA’s annual monitoring report. Validated methods also covered 6-MAM (78 %, n = 21), ketamine (70 %, n = 19), THC-COOH (56 %, n = 15), cotinine (52 %, n = 14), and ethyl sulfate (48 %, n = 13) (Fig. 2, right). Opioids, pesticides, antibiotics, or exposure biomarkers (phthalates, bisphenols, parabens or UV-filters) were some of the additional chemical classes included in their methods.

Participants indicated readiness to expand their analyses in 2024, with 2 additional laboratories capable of adding ethyl sulfate, 4 cotinine, 11 could analyse new psychoactive substances (NPS), and 10 participants could analyse anhydroecgonine methyl ester (AEME) for crack cocaine use estimates. In 2023, 63 % (n = 17) of respondents received national government funding, while others relied on EU funding (26 %, n = 7), private sector contributions (22 %, n = 6), or philanthropic support (4 %, n = 1). However, 22 % (n = 6) reported no funding.

3.3.2. Research and innovation, data utility and needs

Most participants (85 %, n = 23) were actively engaged in WBE-related research and innovation. Activities over the past 5 years included training future professionals, participation in research projects, developing methods for NPS, extending WBE to pathogens using microbiological methods i.e., polymerase chain reaction (PCR) or whole genome sequencing (WGS), and engaging with policymakers and funding agencies.

Regarding interactions with regulatory agencies, 63 % (n = 17) of the participants confirmed their interaction or engagement with law enforcement agencies, ministries, federal office of public health, department of anti-drug policy, or their respective Reitox NFPs. However, 37 % (n = 10) reported not having a solid interaction with any regulatory agency. Regarding data utility, 81 % (n = 22) used results for research publications, while 63 % (n = 17) applied them to public health policy development. Other applications included law enforcement (22 %, n = 6), drug treatment strategies (19 %, n = 5), and harm reduction programs (19 %, n = 5). Some reported additional uses, such as

environmental toxicity assessments and informal reporting to police and customs.

The main challenge for most of the participants was the lack of funding (74 %, n = 20). Insufficient laboratory capacity, equipment, and dedicated staffing issues were also reported. Other barriers were limited sampling coverage, access to sampling points, sample storage, access to accurate population estimates, ethical concerns, and personnel training. The major needs reported by most of the respondents was the prioritization of national long-term funding to maintain trained personnel and laboratory equipment.

3.3. Part 2: Results from Reitox network

3.3.1. Understanding and recognition of WBE

Most organisations (71 %, n = 10) were familiar with WBE for illicit drugs, and the same percentage recognized its potential for drug policies and public health strategies. Two NFPs acknowledged WBE’s value but lacked funding, while two countries did not recognize or utilize it. One of these countries reported not being convinced about the usefulness of WBE providing drug use estimates at city and regional level.

3.3.2. Collaboration with WBE studies and main barriers

Except for one country, all survey participants reported current or previous collaboration with research institutions conducting WBE for illicit drugs. In one case, data for the EUDA annual monitoring program were submitted from 2011 to 2020, but funding issues led to discontinuation. Another country reported having encountered difficulties in 2022, preventing data submission to EUDA. Most participants maintained active collaboration with research institutions providing annual results on illicit drug trends in wastewater. One NFP highlighted monitoring trends in coastal tourist areas, while another described a project expanding since 2017 to cover all national districts with quarterly campaigns and an increasing scope of substances. One country mentioned a strong collaboration with national stakeholders, and another reported a new agreement between the Department for Anti-drug Policies and a research institution to monitor illicit drugs in 38 cities.

Barriers varied depending on the maturity and institutionalization of the WBE systems. In one country, no collaboration exists between decision makers and researchers, leaving respondents unaware of potential

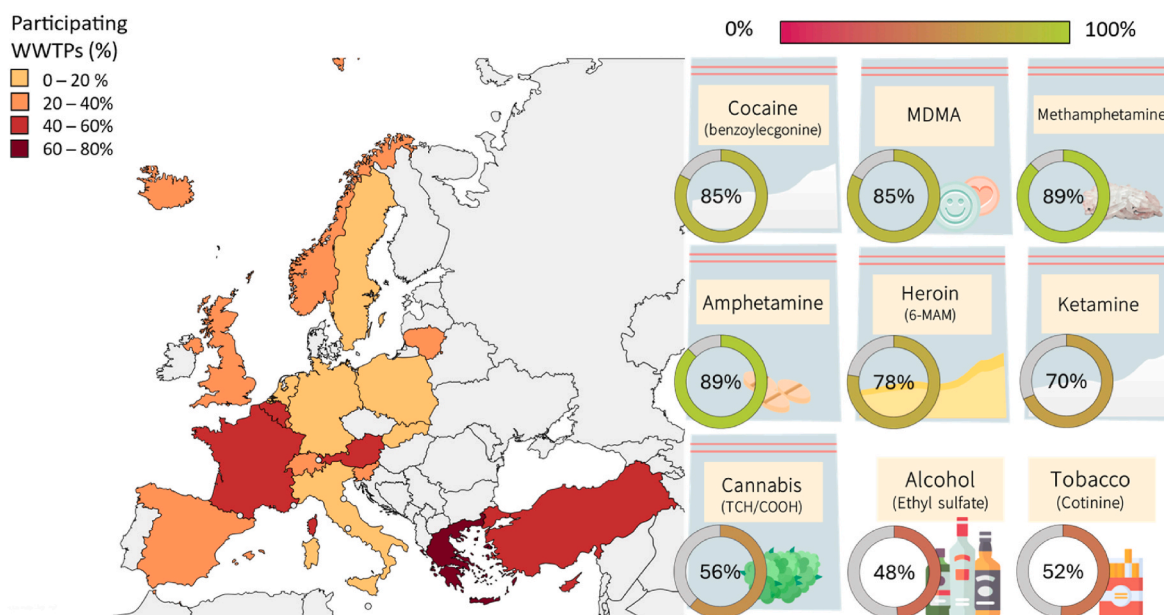


Fig. 2. Percentage of the total national population estimates served by the WWTPs providing wastewater samples to the 27 participants of the survey (left). Percentage of the 27 participants with validated analytical methods to analyse and report different substances from wastewater samples (right).

obstacles. The collaboration with the institutions providing WBE data in a different country stopped in 2017. One participant, despite having interest and funding, failed to establish an agreement with the main forensic toxicology laboratory for analysis. Two countries reported funding as the primary barrier to sustainable WBE systems, even with existing expertise. The remaining countries reported a good collaboration with institutions running WBE analysis.

Some countries reported successful collaborations but reported challenges. One country has a well-established WBE network of cities joining efforts but lacks resources to sustain it. Another is working to raise awareness among stakeholders about expanding analyses to more cities. Technical difficulties in receiving continuous data were reported by one country, while others highlighted challenges in interpreting and presenting WBE data to stakeholders. Miscommunication with the media, leading to sensationalist reporting, was also a concern. Two countries reported no current barriers and strong collaboration frameworks.

3.3.3. Data utility and factors influencing the use of WBE for decision making

Except for four respondents, most participating countries actively used WBE monitoring data in 2023 for national drug reports, professional events, or advisory roles for municipal experts, with some presenting reports to ministries. One country used the data to identify intervention areas, inform national strategies, and collaborate with local law enforcement and policymakers. Beyond funding, key factors limiting WBE use included absence of regular studies, limited city selection affecting national representativeness, insufficient scientific evidence, data quality and reliability issues, and challenges conducting comprehensive cross-indicator analyses. For instance, collecting data for only one week a year provides insufficient precision for supporting drug policy or stakeholder engagement.

Improved data standardization to enhance comparability, such as generating national estimates from multiple locations, was identified as a priority by several NFPs. While most agreed on WBE's utility, one country requested a clear definition of the specific goals and added value compared with existing systems before being used to inform decision makers on the prevalence of substance use at a population-based level.

3.3.4. Future cooperation, coordination, and sustainability

Most NFPs expressed their commitment to continue raising awareness about the importance of WBE and fostering cooperation among stakeholders, including public health and law enforcement agencies, researchers, and community organisations. This includes acting as national hubs for coordination and promoting collaboration among research groups, sharing experiences, and securing future funding. Examples of successful coordination strategies, such as those in Australia¹⁰ and New Zealand,¹⁷ were cited as valuable models for adoption. Increasing WBE visibility through national drug reports was highlighted as a means of engaging international stakeholders like the EUDA.

Building analytical capacity, standardizing reporting protocols, ensuring data quality, and improving interpretation were seen as essential actions to strengthen national laboratories. Respondents emphasized the need for participation in international networks and workshops to exchange knowledge, best practices, and epidemiological insights. Examples of WBE guiding public health or crime prevention policies were noted as particularly helpful by some NFPs.

There was consensus on the need for assistance in securing sustainable funding through grants, partnerships, or government agreements. However, funding needs varied by WBE system maturity: from piloting new systems to improving methodologies, expanding number of locations and frequency, or improving data interpretation. More advanced countries prioritized coordination and knowledge sharing. One NFP requested additional support for defining clear goals, agreeing on methodology with a scientific committee, identifying the added value, and evaluating feasibility and resource needs before obtaining national

funding.

4. Discussion

The findings of these surveys confirm significant advancements within European WBE monitoring activities for illicit drugs streamlined by the SCORE Network. However, challenges, particularly in funding and coordination, remain barriers to optimising WBE's full potential.

Research institutions in Europe have developed sophisticated analytical methods and maintained access to samples with substantial national population coverage. They are also engaged in research and innovation initiatives, increasing their readiness to adapt and provide new methods and tools in response to the needs of decision makers. Notably, two-thirds of the participating countries are currently using WBE data for policy development, with some even informing local law enforcement agencies and policymakers. Despite these advancements, challenges concerning funding to secure experienced personnel and capacities remain.

Most survey participants from the Reitox network recognize the value of WBE data. Several countries have expanded WBE capacities in recent years, reflecting growing interest in this approach. However, they identified several points for improvement according to the level of maturity and institutionalization at national level, including initial cooperation agreements among stakeholders, system operationalization, site selection for optimal national representativeness, resource sustainability, data interpretation, and funding. They also request more frequent sample analysis to improve national estimates and representativeness, better coordination among national WBE stakeholders, and assistance in securing long-term funding.

The survey results underscore the utility of WBE data for various applications, including research, public health policy development, and law enforcement initiatives. However, the survey also reveals complex and heterogeneous levels of governance, institutional recognition, and utilization of WBE data across Europe, influencing its adoption. While some countries exhibit robust collaboration between researchers, ministries, and decision makers, others face barriers such as funding constraints or institutional reluctance. Ensuring the long-term sustainability of WBE will require stable funding, clear governance structures with effective coordination and strong collaboration among stakeholders, and methodological standardization to enhance data actionability for decision making. Strengthening governance frameworks, securing multi-year funding commitments, and increasing cross-sector engagement will be essential to establishing WBE as a long-term public health surveillance tool for illicit drugs. This work contributes to a deeper understanding of the challenges and opportunities in leveraging WBE for illicit drug monitoring and decision making.

4.1. Study limitations

The constrained sample size of the survey is a main limitation, potentially affecting the generalizability of the findings to the broader European context. Additionally, self-reported data introduces susceptibility to response bias and inaccuracies. Nevertheless, this survey provides valuable insights into the status of cooperation and coordination in WBE for illicit drugs across Europe.

4.2. Conclusion

This survey offers valuable insights into the current landscape of WBE for illicit drugs in Europe and underscores the importance of collaboration and coordination among stakeholders. The findings highlight considerable progress within the scientific community in establishing robust infrastructure and validated analytical methods. However, challenges across participating countries persist, particularly in securing funding, achieving methodological sampling standardization, and generating national estimates from multiple locations. Despite

these challenges, there is a shared commitment among stakeholders to enhance cooperation and coordination in WBE, recognizing its potential to inform policies and interventions aimed at reducing drug-related harms.

Moving forward, fostering a culture of collaboration and knowledge sharing within the WBE community is paramount. Immediate actions are needed to foster collaboration, secure sustainable funding, and standardize methodologies across Europe. Collaboration between programs monitoring illicit drugs and pathogens could further enhance efficiency by enabling shared use of wastewater samples for multiple purposes. Practical steps include strengthening collaboration between researchers, decision makers, and funders, establishing clear governance structures at the national level, resource allocation, protocols, and knowledge sharing mechanisms. This could be achieved through national collaboration agreements between research groups and NFPs, supported by EUDA and the SCORE Network. EUDA and SCORE could lead new activities such as interdisciplinary working groups, regular forums for exchanging best practices, and capacity-building initiatives aimed at enhancing new methodological applications and data interpretation.

Finally, the SCORE Network and EUDA should leverage existing initiatives and organisations supporting WBE, such as the Joint Action EU-WISH (www.eu-wish.eu), the Global Consortium for Wastewater and Environmental Surveillance for Public Health (GLOWACON),¹⁸ or the ongoing institutionalized WBE programs in countries such as Australia, Finland or New Zealand. By taking these practical steps, stakeholders can harness the full potential of WBE to inform evidence-based policies and interventions aimed at reducing drug-related harms and improving public health outcomes.

Author statements

Ethical approval

Ethical approval was not required based on the Norwegian Health Research Act since the study did not collect any personal health or sensitive data and participation was entirely voluntary. Survey participants were informed about the purpose of the study and provided their consent for the findings to be submitted for publication.

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Competing interests

Not applicable.

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Appendix A. Supplementary data

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