European Monitoring Centre
for Drugs and Drug Addiction

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PERSPECTIVES ON DRUGS

Wastewater analysis and drugs: a European multi-city study

Wastewater analysis is a rapidly developing scientific discipline with the potential for monitoring real-time population-level trends in illicit drug use. Originally used in the 1990s to monitor the environmental impact of liquid household waste, the method has since been used to estimate illicit drug consumption in different cities (Daughton, 2001; Zuccato et al., 2008; van Nuijs et al., 2011). It involves sampling a source of wastewater, such as a sewage influent to a wastewater treatment plant. This allows scientists to estimate the quantity of drugs consumed in a community by measuring the levels of illicit drugs and their metabolites excreted in urine (Zuccato et al., 2008).

Full edition of this article with interactive features available online at

emcdda.europa.eu/topics/pods/waste-water-analysis

Wastewater testing in European cities

In 2010, a Europe-wide network (Sewage Analysis CORE Group — Europe) was established to standardise the approach to wastewater analysis and to coordinate national studies. Following the success of an initial study in 19 European cities (Thomas et al., 2012) a comparable study was undertaken covering 23 cities in 11 European countries in 2012 and 42 cities in 21 European countries in 2013 (Ort et al., 2014). This approach made it possible to directly compare illicit drug loads in Europe over a one-week period. This was the first time a European-wide study was performed using a standard protocol and a common quality control exercise while covering multiple countries and years ([1]). Raw 24-hour composite samples were collected during a single week in March 2013. These were analysed for the urinary biomarkers (i.e. measurable characteristics) of the parent drug (i.e. primary substance) for amphetamine, methamphetamine and MDMA. In addition, the samples were analysed for the main urinary metabolites (i.e. substances produced when the body breaks drugs down) of cocaine and cannabis, which are benzoylecgonine (BE) and THC-COOH (11-nor-9-carboxy-delta9-tetrahydrocannabinol).

Patterns of illicit drug use: geographical and temporal variation

The project revealed a picture of distinct geographical and temporal patterns of drug use across European cities (see interactive graphic online). The BE loads observed indicate that cocaine use is higher in western and some southern

([1]) The protocol can be found on the EMCDDA website: www.emcdda.europa.eu/wastewater-analysis.

European cities and lower in northern and eastern European cities. Amphetamine use was found to be relatively evenly distributed across European cities, although with highest levels reported in the north and northwest of Europe. In contrast, methamphetamine use is concentrated in cities within the Czech Republic, Slovakia and northern Europe, while the observed methamphetamine loads in the other locations were very low to negligible.

Relatively low levels of the urinary biomarker loads related to MDMA were found in most European countries. The highest loads found were detected in Belgian and Dutch cities.

With regard to cannabis, the identification of THC-COOH loads in wastewater poses some analytical challenges, and as a result not all samples were analysed for this metabolite of THC. In contrast to the other illicit drugs under investigation, it was not possible to establish regional patterns.

The study also highlighted differences among cities within the same country, which may be explained in part by the different social and demographic characteristics of the cities (universities, existence of nightlife area and age distribution of population). In the majority of countries with multiple study locations, cocaine and MDMA loads were generally higher in large cities compared to towns. No such differences could be detected for THC-COOH, amphetamine and methamphetamine loads.

In addition to geographical patterns, wastewater analysis can detect fluctuations in weekly patterns of illicit drug use. In the majority of cities, higher loads of BE and MDMA were detected on Saturdays and Sundays than during weekdays. In contrast, cannabis and methamphetamine use were found to be distributed more evenly over the whole week.

A sub-set of cities were involved in the earliest wastewater study in 2011, and when these first results are compared with data from the 2012 and 2013 periods a stable picture of cocaine use can be observed over time. The general patterns detected were similar in all three years, with the highest and lowest BE loads found in the same cities and regions. In a few cases, in particular in southern and western European countries, a decrease in BE loads was observed between 2011 and 2013. For methamphetamine, the 2013 results showed both a decrease in some cities with high methamphetamine loads in 2011, alongside an increase in some cities with previously low loads detected. Overall, the data related to amphetamine and cannabis from the 2011, 2012 and 2013 studies showed no major changes in the general patterns of use observed. However, some individual cities did show slight increases in MDMA loads.

Comparison with findings from other monitoring tools

The trends and patterns being detected by wastewater analysis are largely, but not completely, in line with the analyses coming from other monitoring tools, such as surveys, treatment demand and law enforcement data. For example, prevalence data from surveys and wastewater analysis both present a picture of a geographically divergent stimulant market in Europe, where cocaine is more prevalent in the south and west, while amphetamines are more common in central and northern countries (EMCDDA, 2014). Data from established indicators and from wastewater also show that methamphetamine use has been primarily concentrated in the Czech Republic, but is now also present in some other countries (EMCDDA, 2014). Similarly, both studies based on self-reported drug use and wastewater data point towards the same weekly variations in use, with stimulants such as amphetamine and cocaine being primarily used at weekend music events and in celebratory contexts (Tossmann et al., 2001).

Some differences between wastewater and other indicator data can be seen in relation to cannabis and MDMA. In line with data from established indicators, wastewater analysis revealed high THC-COOH loads in Spanish and some Dutch cities. However, while Italy and the Czech Republic rank among the high prevalence countries for cannabis, wastewater data did not confirm this. The picture for MDMA is also unclear. There are indications of a recent resurgence of the MDMA market (EMCDDA, 2014), and slight increases were also detected in wastewater compared to 2011, but in general the MDMA loads detected in wastewater remain low.

Limitations of this method

Wastewater analysis offers an interesting complementary data source for monitoring the quantities of illicit drugs used at the population level, but it cannot provide information on prevalence and frequency of use, route of administration, main classes of users and purity of the drugs. Additional challenges arise from uncertainties associated with the sampling of wastewater, behaviour of the selected biomarkers in the sewer, reliability of inter-laboratory analytical measurement, different back-calculation methods and different approaches to estimate the size of the population being tested (Castiglioni et al., 2013b; Thomas et al., 2012). The caveats in selecting the analytical targets for heroin, for example, make monitoring this drug in wastewater more complicated compared to other substances. Also, the purity of street products fluctuates unpredictably over time and in different locations. Furthermore, translating the total consumed amounts into the corresponding number of average doses is complicated as drugs can be taken by different routes and in amounts that vary widely, and purity levels fluctuate (Zuccato et al., 2008).

New developments and the future

Alongside developments in wastewater analysis at the general population level, a new technique has been established that involves the collection and analysis of pooled urine from stand-alone portable urinals. This method can detect both traditional drugs and new psychoactive substances, including previously undetected drugs, even at low concentrations (Archer et al., 2013a; Archer et al., 2013b; Reid et al., 2014).

Wastewater analysis has demonstrated its potential as a complement to established monitoring tools in the drugs area. It has some clear advantages over other approaches as it is not subject to response and non-response bias and can better identify the true spectrum of drugs being consumed, as users are often unaware of the actual mix of substances they take. This tool also has the potential to provide timely information in short timeframes on geographical and temporal trends, but, as is the case with established monitoring tools, this method can be hampered by reporting delays. In order to check the quality and accuracy of data, further comparisons between wastewater analysis and data obtained through other indicators are needed. To date, there have been few attempts to compare estimates produced from wastewater and more established techniques (Reid et al, 2012; Thomas et al, 2012). Nonetheless, as a method wastewater analysis has moved from being an experimental technique to being a new method in the epidemiological toolkit. Its rapid ability to detect new trends can help target public health programmes and policy initiatives at specific groups of people and the different drugs they are using.

Terms and definitions

Back-calculation is the process whereby researchers calculate/estimate the consumption of illicit drugs in the population based on the amounts of the target drug residue entering the wastewater treatment plant.

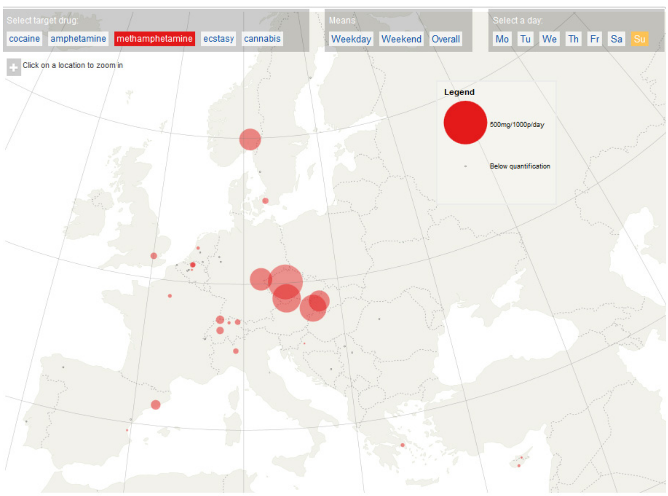
Liquid chromatography–tandem mass spectrometry (LC-MS/MS) is the analytical method most commonly used to quantify drug residues in wastewater. LC-MS/MS is an analytical chemistry technique that combines the separation techniques of liquid chromatography with the analysis capabilities of mass spectrometry. Considering the complexity and the low concentrations expected in wastewater, LC-MS/MS is one of the most powerful techniques for this analysis, because of its sensitivity and selectivity.

Metabolite Traces of drugs consumed will end up in the sewer network either unchanged or as a mixture of metabolites. Metabolites, the end products of metabolism, are the substances produced when the body breaks drugs down.

Residue Wastewater analysis is based on the fact that we excrete traces in our urine of almost everything we consume, including illicit drugs. The target drug residue is what remains in the wastewater after excretion and is used to quantify the consumption of illicit drugs in the population.

Urinary biomarkers Analytical chemists look for urinary biomarkers (measurable characteristics to calculate population drug use) in wastewater samples, which can be the parent drug (i.e. the primary substance) or its urinary metabolites.

Interactive element



Interactive: explore the data from the study, available on the EMCDDA website: emcdda.europa.eu/topics/pods/waste-water-analysis

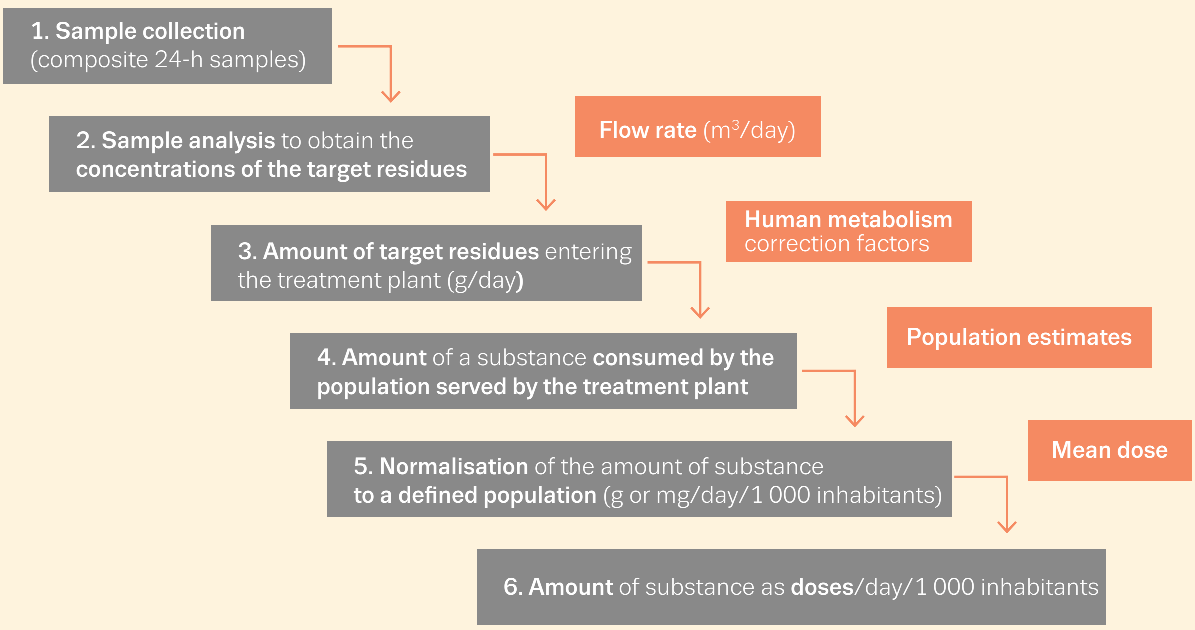
Understanding the wastewater method, and addressing ethical issues

In order to estimate levels of drug use from wastewater, researchers attempt first to identify and quantify drug residues, and then to back-calculate the amount of the illicit drugs used by the population served by the sewage treatment plants (Castiglioni et al., 2013a). This approach involves several steps (see figure). Initially, composite samples of untreated wastewater are collected from the sewers in a defined geographical area. The samples are then analysed to identify concentrations of the target drug residues. Following this, the drug use is estimated through back-calculation by multiplying the concentration of each target drug residue (ng/L) with the corresponding flow of sewage (L/day). A correction factor for each drug is taken into account as part of the calculation. In a last step, the result is divided by the population served by the wastewater treatment plant, which shows the amount of a substance consumed per day per 1 000 inhabitants. Population estimates can be calculated using different biological parameters, census data, number of house connections, or the design capacity, but the overall variability of different estimates is generally very high.

Although primarily used to study trends in illicit drug consumption in the general population, wastewater analysis has also been applied to small communities, including workplaces, schools, music festivals, prisons and specific neighbourhoods.

Using this method in small communities can involve ethical risks (Prichard et al., 2014), such as possible identification of a particular group within the community. Consequently, there is a strong need for ethical guidelines for researchers using this technique (Hall et al., 2012). Ideally these guidelines should be interdisciplinary and international and should entail some consideration of how findings might be interpreted, how media outlets might misrepresent findings and how policymakers may respond (Prichard et al., 2014).

Wastewater analysis approach



Source: (Castiglioni et al., 2013a)

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