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Testing wastewater to detect illicit drugs: State of the art, potential and research needs

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HIGHLIGHTS

- Chemical analysis of urban wastewater is a potent tool to monitor patterns and trends of illicit drug use.
- Wastewater analysis can identify changing habits and the use of new psychoactive substances.
- Wastewater analysis and epidemiological indicators provide highly complementary information.
- The first international conference was organized to gather experts from different disciplines.
- Future challenges to link wastewater analysis and drug epidemiology have been discussed.

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ABSTRACT

Illicit drug use is a global phenomenon involving millions of individuals, which results in serious health and social costs. The chemical analysis of urban wastewater for the excretion products of illicit drugs is a potent approach for monitoring patterns and trends of illicit drug use in a community. The *first international and multidisciplinary conference* on this topic was recently organized to present the epidemiological knowledge of patterns in drug use and the information obtained from wastewater analysis. This paper gives an overview of the main issues that emerged during the conference, focusing on the identified research gaps and requirements and on the future challenges and opportunities from bringing together wastewater analysis and drug epidemiology. The European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) uses an established multi-indicator system to monitor illicit drug use and to identify the emergence of new psychoactive substances. The methodological challenges of monitoring a hidden and stigmatized behavior like drug use include the limitations of self-report data and reporting delays. An increasing evidence base suggests that wastewater analysis can address some of these problems. Specifically this technique can: monitor temporal and spatial trends in drug use at different scales, provide updated estimates of drug use, and identify changing habits and the use of new substances. A *best practice protocol* developed by a Europe-wide network of experts is available to produce homogeneous and comparable data at different sites. The systematic evaluation of uncertainties related to wastewater analysis has highlighted which areas require careful control and those that need further investigation to generally improve the approach. Wastewater analysis has considerable potential to complement existing approaches for monitoring drug use due to its ability to produce objective, real-time estimates of drug use and to give timely information of any change in the patterns of use.

1. Introduction

The chemical analysis of urban wastewater for the combined excretion products of illicit drugs is a potent approach for monitoring patterns and trends of illicit drug use in a community (Castiglioni et al., 2011; van Nuijs et al., 2011a). The approach is based on the fact that traces of almost everything we consume are excreted unchanged or as a mixture of metabolites in our urine and/or feces and ultimately end up in the sewer network. The concentrations of the metabolic residues of illicit drugs measured in raw communal wastewater can therefore reflect the amount of a particular drug that has been used by a population served by a particular sewer network.

The concept originates from research on monitoring the environmental contamination caused by the human excretion of therapeutic drugs. Wastewater analysis was proposed as a *New Non-Intrusive Tool*

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to evaluate the use of illicit and misused drugs in a community (Daughton, 2001), and other following studies demonstrated the occurrence of several misused pharmaceuticals in the environment at concentrations higher than expected (e.g. Calamari et al., 2003) confirming that the same principle could be used to monitor the use of illicit drugs. The approach was for the first time implemented in several Italian cities in 2005 (Zuccato et al., 2005) and was soon applied in several other cities in Europe and the US (Bones et al., 2007; Zuccato et al., 2008; van Nuijs et al., 2009; Kasprzyk-Hordern et al., 2009; Banta-Green et al., 2009). Monitoring a complex, hidden, low prevalence and stigmatized behavior, such as illicit drug use, is a difficult task and conventional approaches face methodological challenges. Among these are the possible response and non-response biases that are associated with self-report survey data. This problem is increasingly complicated by the fact that, especially for new synthetic substances, consumers may simply be unaware or misinformed about the drug they are consuming. National drug surveys are also relatively expensive and thus they are rarely conducted annually. For this reason and because of time needed for the collation and analysis of results a considerable time delay often exists between the sampling and reporting period (European Monitoring Center for Drugs and Drug Addiction, 2008). Testing wastewater for drug residues has the main advantage of providing objective and near-real-time estimates of illicit drug use in a defined population and therefore overcomes some of the limitations inherent to existing methods (Zuccato et al., 2008). The potential of this approach is therefore related to its strong complimentary character with epidemiological tools that in turn, can provide unique information about the frequency and mode of drug use and can identify the main classes of users.

Although in 2008 the wastewater analysis approach was still in its infancy, the European Monitoring Centre for Drug and Drug Addiction (EMCDDA) began to show a strong interest in exploring its potential to complement and extend the existing epidemiologically based illicit drug use estimation techniques (European Monitoring Center for Drugs and Drug Addiction, 2008; Frost et al., 2008).

The wastewater analysis approach has since been applied in many different countries to monitor the use of the main classes of illicit drugs such as cocaine, heroin, cannabis and amphetamines (van Nuijs et al., 2011a; Thomas et al., 2012) and more recently to identify the use of new psychoactive substances (Reid et al., 2013; van Nuijs et al., 2013a). Research has also aimed to identify the uncertainties and research gaps related to this approach in order to minimize and/or control them and improve the reliability of the entire method (Lai et al., 2011; Castiglioni et al., 2013).

In 2010, a Europe-wide network (Sewage analysis CORE group — SCORE) was initiated to standardize the wastewater analysis approach and to coordinate international studies through the establishment of a common protocol of action. The success of the first investigation performed in 19 European cities (Thomas et al., 2012) opened the way for a EMCDDA supported demonstration program in 2012 that included 27 European cities (van Nuijs et al., 2013b).

This emerging scientific field of investigation has a strong multidisciplinary character, involving both environmental and social sciences, and a key challenge is to bring together the different types of knowledge on patterns and trends in illicit drug use available on one hand from epidemiologists, and on the other hand from chemists and engineers. The *Testing the Waters Conference* was the first international and multidisciplinary conference on this topic, organized by the EMCDDA in collaboration with the EU-funded FP7 Marie Curie SEWPROF Initial Training Network (www.sewprof-itn.eu) with the aim of: 1) assessing the state of the art of the wastewater analysis approach, 2) consolidating research findings, 3) identifying common methodologies for wastewater analysis and monitoring, 4) forging links between different scientific disciplines and identifying gaps and research needs [http://www.emcdda.europa.eu/wastewater-analysis]. The conference was a unique and valuable opportunity to gather experts from different areas such as analytical chemistry, physiology, biochemistry, sewage engineering, spatial epidemiology, statistics and conventional drug epidemiology in order to present the main features of the different disciplines involved and develop discussion among experts.

This paper reports an overview of the main issues that emerged during the conference, focusing attention on current research gaps and requirements and on the future challenges and opportunities of bringing together wastewater analysis and drug epidemiology.

2. Drug use monitoring through epidemiological indicators

2.1. Current available indicators

The EMCDDA, the hub for drug-related information in Europe, has an established multi-indicator system for illicit drug monitoring that is based on standardized demand and supply information (Griffiths et al., 2012). Common data collection tools and standard protocols are established for five key epidemiological indicators: general population surveys; problem drug use; treatment demand; drug-related deaths and mortality; and drug-related infectious diseases. In recent years, supply side indicators have been developed in the fields of drug markets (price, purity and seizures) and drug related crime allowing a comprehensive overview of the drug situation. In addition, new psychoactive drugs, threats and developments are monitored through the EU Early Warning System (EWS): seventy-three new psychoactive substances were officially notified for the first time in 2012 via the EWS (EMCDDA-Europol, 2013). By combining multiple drug-related information sources, a more comprehensive analysis and a more accurate picture of the drug phenomenon in a given population can be built up (Griffiths and Mounteney, 2010).

2.2. Potential and limitations

Harmonized definitions and standard methodologies are developed for these key epidemiological indicators by the EMCDDA to allow European countries to collect the information in an increasingly scientifically sound and comparable way. These key indicators have been crucial in facilitating what is now referred to as a *common language* for European countries to compare national conditions and develop an understanding of the European drug situation (Griffiths et al., 2012). Existing epidemiological indicators also provide insights that are not available through, and also complement, wastewater data. These include demographic details, patterns of use and health risk behaviors. Some studies also include attitudinal measures. Understanding different patterns of drug consumption and behavioral correlates is particularly useful for the interpretation of waste water population estimates. The key epidemiological indicators provide a long-term and standardized time series analysis that facilitates a reliable diagnosis of the drug situation.

As drug use tends to be socially stigmatized and hidden, monitoring illicit drug trends also presents a number of methodological and practical challenges. Traditional survey methods, such as general population surveys, are subject to response and non-response biases (Griffiths and Mounteney, 2010) and population surveys are generally regarded as inappropriate method for estimating forms of problem drug use as these users are hard to access by the usual means. For this reason indirect methods, such as multiplier methods and capture–recapture methods, have been developed to offer an alternative way of estimating prevalence of problem drug use (Hickman and Taylor, 2005). In addition, a common challenge for most conventional monitoring tools (surveys, treatment demand, seizures data, etc.) is that they are often time-consuming and complex and require the investment of considerable resources if they are to produce satisfactory and timely results (Griffiths and Mounteney, 2010).