

Wastewater-based epidemiology for public health monitoring



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Wastewater-based epidemiology (WBE) is an innovative and promising approach which enables information about exposure to external agents and disease in defined population groups to be retrieved from wastewater via the analysis of human metabolic excretion products (called biomarkers). This approach is best described as a large urine test, as the collective wastewater represents anonymous urine samples of thousands of individuals.

WBE was first proposed in 2001¹ and applied in 2005². Since then, several research groups across the world have implemented WBE to estimate community-wide drug use at local, national and international scales. WBE complements existing epidemiology-based techniques and provides evidence-based estimates of illicit drug use with relatively accurate detail as to time and location.

The WBE approach is based on the fact that human excretion products of external or internal bodily origin resulting from exposure to foreign chemical compounds (e.g. illicit drugs, food or environmental toxicants and infectious agents) are collected and pooled by the sewage system. This provides valuable evidence of the quantity and type of foreign chemical (or 'xenobiotic') compounds to which a population was exposed, such as protein and DNA biomarkers of cancer, toxicants and the substances known as metabolites that they produce during digestion and other bodily chemical processes. For excretion products which are stable in wastewater and efficiently conveyed to the wastewater treatment plant (WwTP), it is reasonable to assume that the collective amount excreted in a given period is reflected by the load reaching the WwTP in the corresponding interval.

Concentrations of biomarkers in wastewater – obtained with sophisticated, sensitive and selective mass spectrometry techniques – are used to back-calculate the mass loads of biomarkers (e.g. the parent xenobiotic compound and/or metabolites). These loads can then be used to estimate exposure, e.g. drug use (in amount/day), with knowledge of the drug metabolism and excretion patterns. Furthermore, by dividing the rate of drug use by the size of the population served by the WwTP, results can be normalised to population (i.e. mg/day/1000 individuals), allowing results from different locations to be compared. Although this concept is relatively simple, various factors influencing its reliability need to be fully understood before implementation on a large scale is possible. Among the most important factors are: human

metabolic patterns of the investigated xenobiotic agents, characteristics of sewer systems (population size in a WwTP catchment, wastewater flow rate), and understanding the fate of biomarkers (e.g. stability, degradation, partitioning, or sorption in the sewer).

Fast progress in the field of WBE is mainly attributed to successful international pan-European collaboration. The SCORE group, which was established in 2010, brought together experts working on illicit drugs analysis from several European countries (www.score-cost.eu) with the aim of undertaking international studies comparing illicit drug use between major European cities and evaluating different analytical procedures being used in different labs. Supported by the European Monitoring Center for Drugs and Drug Addiction (EMCDDA), the SCORE group has established a wider European network (now including 23 countries) which allowed an international study on the analysis of wastewater to be undertaken for the first time, with the aim of estimating the use of illicit drugs on a European scale³.

Europe-wide monitoring campaigns are now undertaken every year. This started with 19 cities in 11 countries in 2011 and covered 42 cities in 21 countries in 2013 (see Figure 1). During a one-week monitoring period, samples from the wastewater of a total of over 24 million people were collected every day and analysed by project partners for the following substances: Benzoylcegonine (main excretion product from cocaine consumption), MDMA (ecstasy), amphetamine and methamphetamine as well as THC-COOH (excretion product from cannabis consumption).

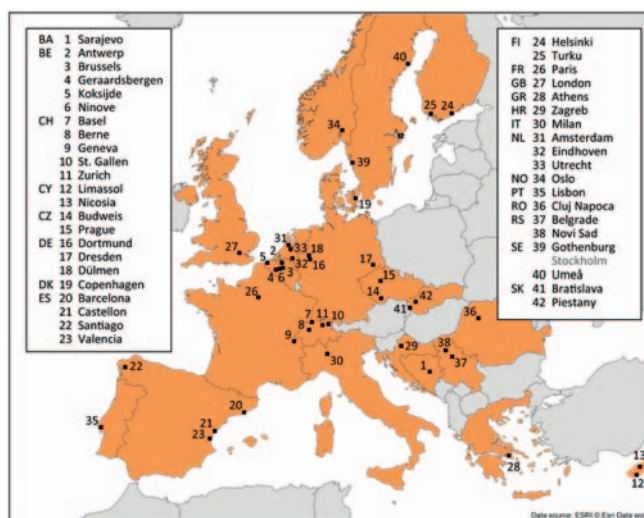


Figure 1: Forty-two cities, with a total population of approx. 24 million, participated in the study's European monitoring campaigns in 2013

Cocaine was found in almost all cities that participated. By and large, the total consumption did not change over the three years and the overall patterns remained more or less the same. The consumption of amphetamine and methamphetamine revealed distinctive spatial differences. Amphetamine use is more widespread in western Europe, while the use of methamphetamine is clearly shown in northern and eastern Europe. The German results confirm this trend, where in Dülmen and Dortmund (western Germany), relatively high amphetamine and negligible methamphetamine use was observed, while in Dresden (eastern Germany) the opposite was found⁴.



Information gathered from sewage systems across Europe has revealed interesting patterns in drug, alcohol and tobacco use

In 2012, in order to develop trans-disciplinary and cross-sectoral European research capability in the field of WBE and to develop and expand an existing pan-European inter-disciplinary network, the SCORE group received funding from the European Commission to establish a European Marie Curie Initial Training Network, SEWPROF ITN (www.sewprof-itn.eu), followed by further EU funding in 2014 to establish a COST action (www.score-cost.eu). Both initiatives aim to advance knowledge of WBE and to bridge gaps in the available expertise with the ultimate goal of applying this cutting edge inter-disciplinary approach within epidemiological studies of societal health.

Urban wastewater contains a complex mixture of chemical substances including a wide range of human metabolic products. The quantitative measurement of these specific metabolic residues (biomarkers) in sewage from different communities allows information to be obtained on different factors related to lifestyle. Thus far, this approach has been successfully used to determine, apart from illicit drug use, the profiles of alcohol⁵, tobacco use⁶ and counterfeit medicines⁷. The same approach is now being extended to other biomarkers for the assessment of community health⁸, as wastewater can be considered as a 'diagnostic medium for the city'. For instance, new applications can give information about diet, diseases, health status and exposure to environmental and food contaminants.

There is the clear potential to develop a wider range of innovative solutions to quantitatively assess patterns of factors related to health and illness within populations, while also providing a means of collecting data for epidemiological and socio-economic studies in order to evaluate public health. This is now under investigation within the above-mentioned SEWPROF ITN and the COST action.

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