Impact of sampling resolution on estimation of community-wide daily illicit drug use

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Impact of sampling resolution on estimation of community-wide daily illicit drug use

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Summary
It is a common approach to report daily community-wide drug consumption, based on single daily measurements of the influent from a treatment plant. This article suggests that neglecting diurnal variations of loads and flow can result in misestimating daily drug consumption.

Keywords: Sewage epidemiology, In-sewer transformation

Introduction
Over the past decade, sewage-based epidemiology has emerged as a useful technique to provide policy makers with improved knowledge about consumption of illicit drugs. There have been several sources of uncertainty identified and addressed in the literature associated with the estimation of community drug usage employing sewage-based analysis (Castiglioni et al. 2013). Among these are the wastewater sampling best practice protocol (Ort et al. 2013) and the in-sewer biotransformation model (Plósz et al., 2013). However, there has been little focus on the biotransformation of illicit drugs in sampling guidelines. Drug use is usually reported as daily consumption (g $d^{-1}1000PE^{-1}$), based on the analysis of daily composite samples. This approach neglects diurnal variations of consumption and assumes constant drug excretion throughout the entire day. However, by considering diurnal variations of drug load, flow (or average hydraulic residence time) and total suspended solids (TSS) measured at a sampling point (taking more than one sample per day), the sum of back calculated drug use at each sampling interval is different when only one average value (one sample per day) is measured at the sampling point. In fact, considering different numbers of samples per day leads us to estimate different levels of daily drug use. This is simply due to the fact that biotransformation combined with sorption models for trace organics usually applies pseudo first-order reaction rates. Such impact on daily drug estimation is investigated in this article by presenting results from a sampling campaign in Lynetten, Copenhagen (Denmark).

Materials and methods
Lynetten catchment serves 531,000 inhabitants (last census: 2009). A two-week monitoring campaign (28-May – 11-June 2014, including a festival) for the purpose of illicit drug biomarker detection was performed at two inlets of the treatment plant; north catchment (mainly suburbs) and south catchment (city center). 6-hourly flow proportional samples were taken using portable automatic samplers. At the end of each day, acidified samples (pH~4.5) were transported to a freezer and stored at -20°C until the time of analysis. Analysis was carried out on a Waters Acquity UPLC system, with a Xevo G2-S QTOF detector. To simulate biotransformation and sorption processes in the sewer network, Activated Sludge Model for Xenobiotic trace chemicals, ASM-X (Plósz et al., 2013) was used. Monte Carlo method, employing Latin Hypercube Sampling (LHS) of parameter space was used to cover the range of estimated parameters found in the literature (Bisceglia et al., 2013).

Results and discussion
Cocaine (COC) and its major metabolite, benzoylecgonine (BE), were measured during the sampling campaign. Flow and TSS were measured every 2 min and 1 min, respectively. A simple scalar model by Plósz et al., (2013) is used to calculate average in-sewer hydraulic residence time. Figure 1 plots the concentrations determined from the south catchment (main festival sites). ASM-X model parameters for biotransformation and sorption reported by Plósz

et al., (2013) was used as the first reference. COC abuse rate is estimated based on BE and COC biomarkers, back calculated at the theoretical release point. This is done at multiple resolution levels: (i) high resolution sampling; 720 samples per day, (ii) low resolution sampling; 1 to 24 samples per day. Results obtained with each sampling resolution were compared and the difference is reported as error %. Fig. 2 shows the results corresponding to weekdays. Higher resolution of targeted drugs monitored per day was synthetically made by fitting 5th order polynomials to 4 measured data sets per day. Considering an acceptable error of 5%, a minimum number of samples per day is estimated from the Fig. 2 (i.e. around 8 samples). The degree of non-linearity in the concentration attenuation is a function of the biotransformation rate, k_{bio} and sorption parameters k_d values used for calibration. LHS sampling method (2000 samples) was used with the following settings: for COC, $k_{bio,COC}$, ranges from 2-22 (L gTSS^{-1} d^{-1}) and $k_{d\,COC}$, ranges from 0-2 (L gTSS^{-1}), for BE, $k_{bio,BE} = 0.36.k_{bio,COC}$ and $k_{d,BE}$=0. Back calculation was done and a minimum number of samples were determined for each LHS sampling point considering 5% as acceptable error. Fig. 3 shows the minimum number of samples for all LHS samples corresponding to weekdays, and indicates that reliable observation for some chemicals may require as many as 24 samples per day. Results presented in this article introduce the importance of a new sampling protocol by optimising the sampling resolution as a function of reaction kinetics, to more accurately estimate daily drug use in communities.

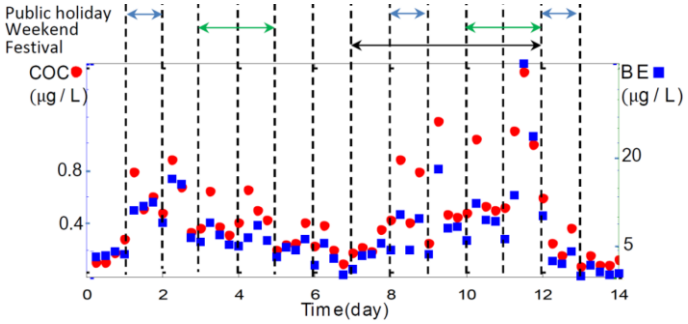

Figure. 1 concentration of COC and BE from Lynetten south catchment over two-week sampling campaign

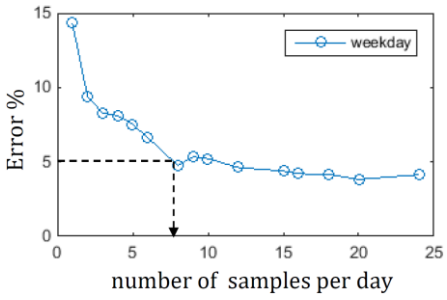

Figure 2. Difference between back calculated COC with low (1 to 24) and high resolution (720) sampling per day, and determination of the minimum number of samples per day.

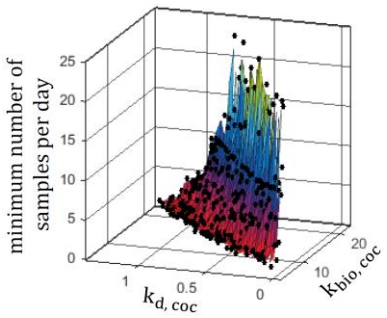

Figure 3. Minimum number of samples as a function of kinetic ($k_{bio,COC}$) and sorption ($k_{d,COC}$) parameters. Data corresponds to weekday.

References

Bisceglia, K. J. & Lippa, K. A., (2013). Stability of cocaine and its metabolites in municipal wastewater-the case for using metabolite consolidation to monitor cocaine utilization. Environ Sci Pollut Res., 21, 4453–4460.

Castiglioni S, Bijlsma L, Covaci A, Emke E, Hernandez F, Reid M, et al. (2013) Evaluation of uncertainties associated with the determination of community drug use through the measurement of sewage drug biomarkers. Environ. Sci. Technol., 47, 1452–1460

Ort C, Lawrence MG, Rieckermann J, Joss A. (2010) Sampling for pharmaceuticals and personal care products (PPCPs) and illicit drugs in wastewater systems: are your conclusions valid? A critical review. Environ. Sci. Technol., 44, 6024–6035.

Plósz, B.G., Reid, M.J, Borup, M., Langford, K.H., Thomas, K.V. (2013). Biotransformation kinetics and sorption of cocaine and its metabolites and the factors influencing their estimation in wastewater. Water Res., 47, 2129–2140.