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Estimation of illicit drug consumption in urban areas based on human metabolism, wastewater data and biodegradation in sewer networks

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Poster presentation

Abstract

We present a method to estimate the illicit drug consumption in an urban area using analytical data obtained in pre-clarified municipal sewage. In this outline paper, we only demonstrate our research work using concentration data obtained for cocaine (COC). The estimation technique developed for COC consumption is based on results obtained on biotransformation of the two major human metabolites, benzoylecgonine (BLG) and ecgonine-methylester (EME) in municipal sewage. The contaminant EME is a human metabolite, whilst BLG is both a human metabolite and a biological transformation product of COC. A novel method, reported by Plósz et al. (2010), was used to solve the inverse problem of inferring process rate and correction factor parameter values from batch experimental results obtained under aerobic and anaerobic conditions. Based on experimental data, revealing solid-liquid partitioning to BLG insignificant, we assume a uniformly low partitioning coefficient, K_D [L g X_{SS}^{-1}] value for all compounds, i.e. 0.01, in the calculation scheme. Instead of spiking the batch reactors with reference substances, measurements were made using the xenobiotic organic micro-pollutant content of pre-clarified municipal sewage (see Fig. 1).

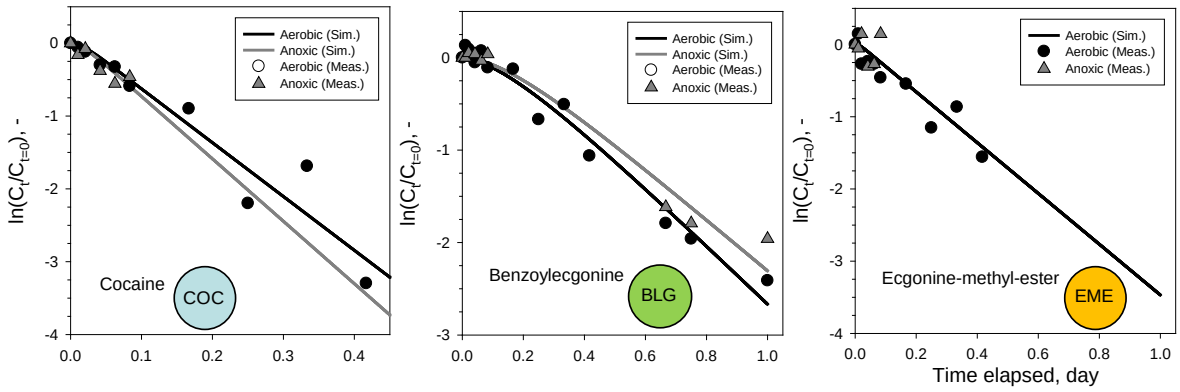

Figure 1. Values of COC (A-left), BLG (B-middle) and EME (C-right) concentration measured (symbols) and simulated (solid black and grey line) in the aerobic and anaerobic batch tests in the liquid phase, C_{LI}.

In the model structure identified for COC fate, the pseudo-first order biodegradation rate equation was extended with an inhibition term to account for competitive inhibition by readily biodegradable substrates, contained in municipal sewage, on the co-metabolic micro-pollutant biotransformation process. Under aerobic to anaerobic conditions, biodegradation rate values obtained under aerobic conditions were significantly higher than under anaerobic conditions, a factor that is additionally accounted for in the model structure. In the batch data obtained for BLG, compound formation was observed that we accounted for in the biokinetic model as a result of COC biotransformation to BLG. The COC biodegradation rate, k_{Bio}, and the initial compound concentration values were then used to assess the initial BLG concentration and its biodegradation rate value using the batch experimental data obtained for BLG. The biodegradation process of EME is described using a pseudo-first order kinetic expression. A full-scale measurement campaign was additionally undertaken in a full-scale sewage

treatment works in Oslo, Norway, in which we collected samples from the pre-clarified sewage in a six-week period, under dry-weather conditions. In the back-calculation method developed, the analytical solutions of the biodegradation rate equations of the transformation product and human metabolites are implemented using the analytical data obtained for BLG and EME as well as hydraulic data characteristic to the combined sewer system. The method developed additionally accounts for the different consumption rates obtained on week days, weekend days and during national events, and results obtained are shown in Fig. 2.

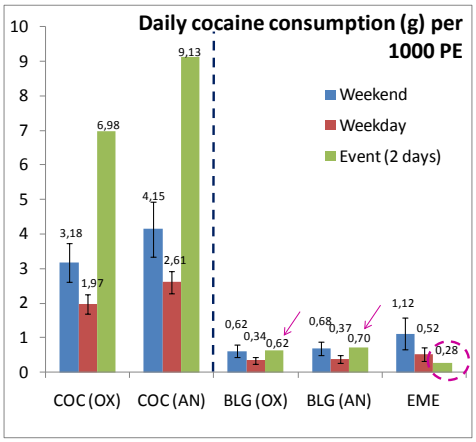

Figure 2. Values of daily cocaine consumption normalised to a thousand inhabitants, obtained using the estimation method developed based on COC, BLG and EME concentration data.

Results obtained for COC consumption based on the BLG and EME data show very close agreement the entire six-week period. Conversely, we demonstrate that any approximation of the illicit drug consumption based on parent COC compound concentration values detected in the pre-clarified influent effectively resulted in unrealistically (4-17 times) higher consumption rates than those obtained based on human metabolites. For the Oslo area, between Monday and Thursday, and between Friday and Sunday, our assessment indicates approximately 0.4 and 1.94 g d^{-1} per 1000 inhabitants of cocaine consumption, respectively. For a national holiday event, COC consumption based on the BLG data suggest consumption comparable to that obtained in the weekend days, which is not the case for EME. Our data additionally show a significantly different distribution of human metabolites and parent compound occurrence and thus COC consumption estimates based on sewage data. This result can, in part, be explained by the possible different drug metabolism caused by, for instance, different COC to alcohol consumption ratio during the national holiday. For Norway (total population: 4.86 M), based on the metabolites/transformation product data, the annual COC consumption calculated is 1.89 t/y. This value is approximately 10% higher than that obtained by omitting compound biodegradation in the sewer system upstream to the sampling point. With a 1.4% prevalence ratio, reported in the UNODC (2010), the annual COC consumption mass calculated in this study result in 25.2 M doses per annum, i.e. 370 doses per user population. Considering an average 30.2 grams per user per year drug consumption rate (UNODC, 2010), with the 1.89 tonne annual consumption, however, we obtain 62 460 users that is only 1.29% of the population. The possible benefits of using the above method can be sought in an improved assessment of regional drug retail and prevalence; that can potentially contribute to developing more effective regional mitigation means, e.g., financing regional public health programs.

Keywords: Illicit drug consumption, back-calculation, municipal wastewater.

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