An Estimation of Illicit Drugs from Chemical Measurements in Municipal Wastewater

Over the last decade, municipal wastewater has been recognized as a substantial reservoir for pharmaceutical and personal care products (PPCPs) and their bioactive metabolites that are excreted from human usage. As originally proposed by Daughton and Ternes [1], illicit drug usage at both the community and metropolitan level may potentially be estimated from chemical measurements within municipal wastewater systems. In this context, NIST has developed a robust analytical methodology for the quantification of drugs of abuse and their respective metabolites in wastewater matrices. This method is intended for the determination of the chemical profiles of cocaine and its major metabolites in wastewater matrices and for the characterization of the major component removal processes in sewer systems. Ultimately, deterministic/stochastic models that include uncertainty analysis will be developed to describe component transport (and determine origin) within municipal wastewater systems and allow for the estimation of drug usage within a selected municipality and its population.

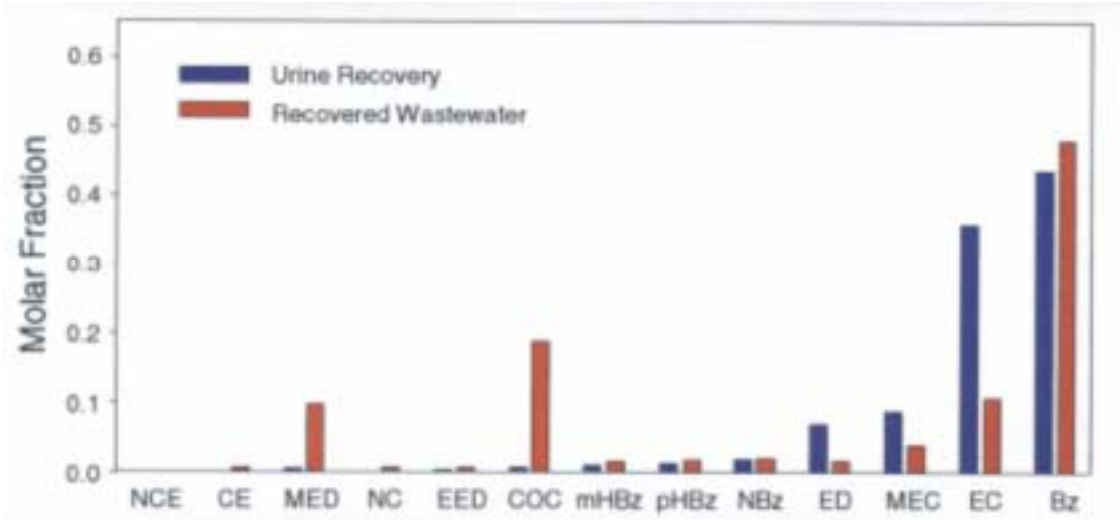
R.M. Heltsley, P.R. Becker, J.R. Kucklick, A.M. Peck, M.M. Schantz, and K.A. Lippa (Div. 839)

According to the 2005 National Survey on Drug Use and Health (NSDUH) [2], approximately 22 million Americans aged 12 or older were classified with a substance or drug dependency. Surveys coupled with crime statistics are typically used to estimate drug consumption rates but may under represent the magnitude of the problem as they are based primarily on voluntarily provided information. Thus, development of real-time analytical methodologies for the analysis of sewage treatment facilities influent waters have been proposed as a means to indirectly and non-intrusively monitor the drug usage within a population. By developing rigorous analytical methods that reliably and accurately determine the concentrations of drugs and their respective metabolites in wastewater, NIST is facilitating an objective, scientific-based approach to the assessment of community-wide drug use.

After a review of the pertinent pharmacology and forensic science literature, we have compiled a list of probable cocaine metabolites (including unique metabolites from pyrolysis or "smoking" activities) that may enter municipal wastewater through human urine input. A comprehensive study to characterize the concentration of cocaine and its metabolites in human urine was recently conducted and are illustrated in ***Figure 1***. These data collected from 17 living individuals were used to generate an average for the relative amounts of each cocaine metabolite present in urine and were used as an initial estimate of the input profile of these components into the sewer system.

NIST has developed an isotope dilution liquid chromatography-tandem mass spectrometry (LC/MS/MS) method to quantify concentration levels of cocaine and its major metabolites [cocaine, cocaethylene, benzoylecgonine, norcocaine, norcocaethylene, norbenzoylecgonine, ecgonine, ecgonine methyl ester, ecgonine ethyl ester, *m*-hydroxybenzoylecgonine, anhydroecgonine (ecgonidine), and anhydroecgonine methyl ester (methyl ecgonidine)] in wastewater and surface water. Method development has been conducted by team members located at the Hollings Marine Lab in Charleston, SC, and the method was applied to various municipal wastewater samples obtained from the Plum Island Wastewater Treatment Plant in Charleston.

A typical molar fraction profile of cocaine and its major metabolites in wastewater are compared with the urine profiles reported by Paul et al. in Figure 1. The appreciably different chemical profiles between the urine input and the wastewater samples suggest that significant transformation processes are occurring within the sewer system.



***Impact*:** The new analytical method represents the first step in developing comprehensive environmental measurement protocols to monitor and predict the usage of illicit drugs. At-risk communities could be readily identified with such monitoring approaches, thus facilitating social, community, and education-based programs intended to reduce and ultimately prevent drug use within our population.

***Future Plans*:** We are in the process of adapting methods for the measurement of illicit drugs in the solid material component of wastewater. The potential environmental fate of cocaine and its metabolites (i.e., hydrolysis, mineral catalysis, sorption, microbial degradation) are presently being characterized through laboratory kinetic reactor experiments; these data are expected to elucidate the potential sinks and sources for cocaine and its metabolites within the sewer environment.

***References*:**

[1] Daughton, C.G.; Ternes, T.A. *Environ. Health Perspect*. **1999**, *107* (suppl 6), 907-938.

[2] Substance Abuse and Mental Health Services Administration. (2006). *Results from the 2005 National Survey on Drug Use and Health: National Findings* (Office of Applied Studies, NSDUH Series H-30, DHHS Publication No. SMA 06-4194). Rockville, MD.

[3] Paul, B.D., Lalani, S., Bosy, T., Jacobs, A.J., Huestis, M.A. *Biomedical Chromatography* 19: 677–688. 2005.