Science of the Total Environment 633 (2018) 249–256

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Estimation of the consumption of illicit drugs during special events in two communities in Western Kentucky, USA using sewage epidemiology

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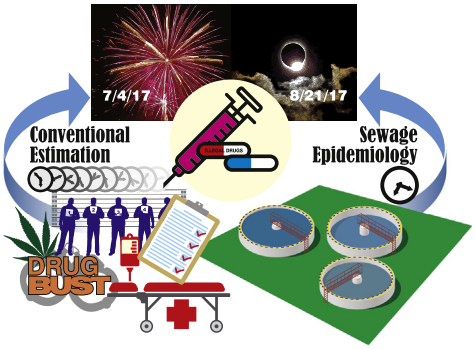
HIGHLIGHTS

- Consumption rates of illicit drugs during special events were determined using sewage epidemiology
- Per-capita consumptions of illicit drugs were significantly different between two similar-sized communities
- Consumption rates of illicit drugs were significantly higher on Independence Day and/or the solar eclipse observation day
- Percentage population that consumed cocaine was similar to the conventional estimate
- Percentage population that consumed amphetamine and methamphetamine was >2 fold higher than the conventional estimate

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 29 January 2018
Received in revised form 15 March 2018
Accepted 16 March 2018
Available online xxxx

Editor: D. Barcelo

Keywords:
Illicit drugs
Wastewater
Sewage epidemiology
Drug consumption
Suspended particulate matter
Special events

ABSTRACT

Sewage epidemiology is a cost-effective, comprehensive, and non-invasive technique capable of determining semi-real-time community usage of drugs utilizing the concentration of drug residues in wastewater, wastewater inflow, and the population size served by a wastewater treatment plant. In this study, semi-real-time consumption rates of ten illicit drugs were determined using sewage epidemiology during special events including Independence Day, the 2017 solar eclipse, and the first week of an academic semester in the Midwestern United States. The average per-capita consumption rate of amphetamine, methamphetamine, cocaine, and THC were significantly different between two similar-sized communities during Independence Day observation week ($p < 0.046$) and a typical week ($p < 0.001$). Compared to a typical day, the consumption rate of amphetamine, methamphetamine, cocaine, morphine, and methadone was significantly higher on Independence Day ($p < 0.021$) and during solar eclipse observation ($p = 0.020$). The estimated percentage of the population that consumed cocaine in a community is similar to the conventionally estimated consumption of cocaine; however, the combined estimated population that consumed amphetamine and methamphetamine based on sewage epidemiology was ~2 to 4 fold higher than the conventional estimates. This study is the first to compare community use of drugs during special events in the USA using sewage epidemiology.

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https://doi.org/10.1016/j.scitotenv.2018.03.175
0048-9697/

1. Introduction

Drug abuse is a global burden for public health as well as for social and economic welfare. In the USA, drug abuse has been a major public concern over a half a century, and the recent opioid epidemic has been declared as a national public health emergency (Johnson and Wagner, 2017). In 2016, approximately 7.4 million people aged ≥12 had an illicit drug use disorder (UNODC, 2017b). In that year, the total drug-related deaths increased by 11.5% to the highest level ever recorded accounting for nearly one-quarter of drug-related deaths worldwide (UNODC, 2017b). Midwestern and Southeastern United States, as transshipment and distribution hubs for drug trafficking organizations, are facing an epidemic level of diversion and abuse of drugs including cocaine, opioids, methamphetamine, marijuana, and heroin (KODCP, 2015; USDJ, 2011). The total heroin seizures in the state of Kentucky increased by 428% from 2010 to 2013 (USDEA, 2014). In addition, clandestine meth-labs and indoor/outdoor cannabis cultivation in this region have consistently posed a threat of drug abuse (KODCP, 2015; USDJ, 2011).

Conventional methods of determining the rate of drug use in a community consist of self-reported surveys, overdose/toxicological reports, and drug-related crime statistics (Asimakopoulos and Kannan, 2016; Banta-Green et al., 2009; Subedi and Kannan, 2014). Self-reported surveys suffer from high cost, time delays for the prompt need of intervention, low coverage, and biases including nonresponse bias and bias in the selection of sample populations with higher use of drugs (Keshaviah et al., 2016).

Sewage epidemiology can provide a more comprehensive, real-time, and cost-effective measure of drug abuse in a community as a complement to other conventional methods (Subedi, 2018; Subedi and Kannan, 2014). Sewage epidemiology, a rapidly expanding approach of determining community usage of drugs, utilizes the concentration of target drugs (and/or metabolites) in wastewater influent from centralized wastewater treatment plants (WWTPs), wastewater inflow, and the population size and location served by WWTPs to back-calculate the per-capita rate of drug use. The usefulness and limitations of the sewage epidemiology approaches have been reviewed in detail elsewhere (van Nuijs et al., 2011a, 2011b). Though many European countries including Italy, Spain, Switzerland, and the UK have successfully utilized sewage epidemiology to provide an early warning system of new drugs of abuse, identify the effectiveness of new drug treatment and prevention, and identify susceptible areas/populations for policy development (Been et al., 2015; Castiglioni et al., 2014; Gonzalez-Marino et al., 2016; McCall et al., 2016), sewage epidemiology has been underutilized in the USA (Chiaia et al., 2008; Subedi and Kannan, 2014).

Contrary to conventional methods of drug use estimation, sewage epidemiology operates on a rapid timescale, such that day to day variations in drug use can be measured. Lai et al. found that the consumption of illicit drugs such as cannabis, cocaine, MDMA (3,4-methylenedioxymethamphetamine), and methamphetamine during special events such as Christmas and New Year's Eve increased in urban areas in Australia (Lai et al., 2013a). MDMA was found an order of magnitude higher in wastewater during youth music festivals in Taiwan and Australia (Jiang et al., 2015; Lai et al., 2013b). However, only one study to our knowledge reported the variability in the rate of consumption of illicit drugs during a special event in the USA - cocaine consumption was slightly elevated during the Super Bowl game weekend whereas methamphetamine consumption was decreased (Gerrity et al., 2011).

In this study, community usage of three stimulants (cocaine, amphetamine, and methamphetamine), three narcotics (heroin, morphine, and methadone), four hallucinogens [MDMA, MDEA (3,4-methylenedi oxyethylamphetamine), MDA (3,4 methylenedioxyamphetamine), and THC (Δ^9-tetrahydrocannabinol)], and seven of their metabolites were determined in wastewater influent from two WWTPs in two similar-sized communities (A and B) in Western Kentucky. Residual levels of illicit drugs were utilized to determine the per-capita usage of drugs in both communities during special events including Independence Day, the 2017 solar eclipse, and the first week of an academic semester versus a typical week. Independence Day (July 4th) is one of the most celebrated national holidays in the USA; therefore, per-capita use of drugs during Independence Day was assessed in both communities. The total solar eclipse on August 21st 2017 was visible across the entire contiguous USA after ~100 years and observed by ~100,000 people in the western belt of Kentucky including the community B. In one of the communities under this study, university professionals/students constitute ~40% of the population. Population dynamics of a student-dominant community can be significantly altered during the first week of an academic semester. In addition, estimated per-capita usage of illicit drugs in this study was compared to a similar study in New York, USA as well as survey-based estimations of use of drugs reported by the United Nations Office on Drugs and Crime (UNODC) and the Substance Abuse and Mental Health Service Administration (SAMSHA). This study is the first to compare special occasion drug use using sewage epidemiology in the USA.

2. Materials and methods

2.1. Sample collection

Wastewater influent (24-h composite of aliquots of every 15 min using time-proportional autosampler at ~8:00 AM) samples were collected in one-liter capacity certified amber glass bottles (Fisher, Hampton, NH) from two WWTPs (designated A and B) in Western Kentucky and transported on ice to Murray State University. Samples were collected for seven consecutive days from both WWTPs on June 30th to July 6th (covering the US Independence Day celebration) and July 26th to August 1st, 2017 (a typical week). $WWTP_A$ was also sampled from August 11th to August 17th (first week of University's academic semester). $WWTP_B$ was also sampled from August 19th to August 22nd (a total solar eclipse observation day). $WWTP_A$ treats an average of 4.56 million gallons per day (MGD) of wastewater serving ~20,000 people whereas $WWTP_B$ treats an average of 6.42 MGD of wastewater serving ~25,000 people. The wastewater treated by both WWTPs constitute ~90% domestic origin. Influent samples were collected after the primary screening of large-sized debris and grit removal.

2.2. Sample preparation

One hundred milliliters of wastewater samples were centrifuged (Thermo Scientific, Waltham, MA) at 4500 rpm (1924 ×*g*) for 5 min and vacuum-filtered through 1.0 μm glass fiber filter paper for the separation of solid particulate matters (SPM). The SPM was stored at −20 °C until extraction. Filtered wastewater samples were spiked with a mixture of internal standards (50 or 150 ng each, list of standards are provided in Supporting Information, SI) and extracted using an Oasis HLB solid phase extraction (SPE) cartridge (200 mg, 6 cm^3, Waters, Milford, MA) within 12 h of sample collection. SPE cartridges were conditioned with 3 mL of methanol and 3 mL of ultrapure water, extracted wastewater samples at ~1 mL/min, and eluted with 4 mL of methanol followed by 3 mL of 5% ammonia in methanol. The combined eluate was concentrated to ~500 μL under a gentle stream of nitrogen using the Reacti-Vap™ Evaporator (Thermo Fisher Scientific, Waltham, MA). The concentrate was quantitatively transferred to an amber liquid chromatography vial, and the final volume was adjusted to 1 mL with methanol. SPM were spiked with a mixture of internal standards, vortexed with 6 mL of methanol for ~5 min, and ultrasonicated (Branson CPXH series) for 30 min. The supernatant liquid was collected, and the extraction was repeated with another 6 mL of methanol. Extracts were combined, concentrated to ~500 μL under a gentle stream of nitrogen, quantitatively transferred to an amber LC vail and adjusted to a final