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Running title: Wastewater study of drug use in Auckland

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Abstract

Introduction – New Zealand is considered to have unusual drug use patterns by international standards. However, this understanding has largely been obtained from social surveys where respondents self-report use.

Aim – To conduct the first wastewater study of drug use in Auckland

Design and Methods – Wastewater sampling was completed from the 2nd May–18 July 2014 at two Auckland wastewater treatment plants which service 1.3 million people. Samples were analysed for 17 drug residues using liquid chromatography-tandem mass spectrometry. Consumption of methamphetamine, 3,4-methylenedioxymethamphetamine (MDMA), cocaine, codeine and methadone (mg/day/1000 people) was estimated using a back-calculation formula.

Results – Methamphetamine, codeine, morphine and methadone were detected with high frequency (80–100%), followed by amphetamine (~60%), MDMA (~7%, i.e. eight occasions), and methylone (on only three occasions). An overall mean of 360 milligrams of methamphetamine and 60 milligrams of MDMA was estimated to have been consumed per day per 1000 people. Methamphetamine consumption was found at similar levels in both catchments (377 & 351 mg/day/1000 people). Cocaine was only detected in one catchment and on only eight occasions. JWH-018 was detected in one catchment and only on one occasion. Methamphetamine, codeine and other opioids were detected at a consistent level throughout the week. MDMA and methylone were detected only during the weekends.

Conclusions – Wastewater analysis confirms that methamphetamine was one of the most commonly used illegal drugs throughout Auckland, and was used consistently throughout the week. In contrast, cocaine and MDMA were used rarely, with use limited to weekends.

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Introduction

New Zealand is considered to have some unusual recreational drug use patterns compared to many other developed Western countries, including Australia, with low levels of cocaine and heroin use but relatively high levels of methamphetamine use (1-4). This unusual prevalence of drug use is attributed to a range of factors including New Zealand's geographical isolation,, small population, and tight border control (5). However, this picture of New Zealand drug use has largely been obtained from general population social surveys of drug use which have a number of well-known limitations [6].

An established strategy to address the limitations inherent in all drug monitoring sources is to draw on multiple monitoring sources with different methodologies (3,4,6). Wastewater analysis (WWA) is one such new approach and is increasingly part of the drug monitoring toolkit (7). WWA estimates drug consumption levels for a given population based on minute concentrations of excreted drug metabolites in pooled samples of raw wastewater collected at the inlet of wastewater treatment plants (8-10). WWA offers objective estimates of drug use for a given local catchment, which are not affected by the limitations of social surveys. WWA studies commonly involve daily sampling which can provide temporally finely-grained trend data on drug use (11, 12) and minimise privacy issues as mass-pooled wastewater guarantees anonymity (13). WWA has been conducted in cities in Europe, North America, Asia and Australia (14-20), but to date, no WWA study has been completed in New Zealand.

This paper presents the findings from a pilot WWA study conducted in New Zealand's largest city, Auckland.

Methods

Wastewater sampling

Wastewater was sampled daily during 2 May-18 July 2014 at two wastewater treatment plants (WWTPs). These two WWTPs service urban catchments of the Auckland region. The first WWTP catchment services about 1.1 million people from the Auckland City, Papakura, Waitakere and Manukau suburbs (WWTP-A). The second covers about 230,000 people mainly from the Northshore (WWTP-B). The population data were estimates provided by the WWTP operators.

Over the monitoring period, a total of 65 daily composite samples were collected at the WWTP-A using time-proportional sampling mode (100 mL/15 min.). This included samples from eight Mondays and Tuesdays, 11 Wednesdays and Fridays, 10 Thursdays and Saturdays and seven Sundays. A total of 40 daily composite samples were collected at the WWTP-B using volume-proportional sampling mode (200 mL/1000 m^3 wastewater). This included samples from eight Mondays, Thursdays and Sundays, seven Tuesdays and Wednesdays, one Friday and one Saturday. Routine sampling was not conducted on Fridays and Saturdays at WTTP-B. Samples were preserved at pH 2 using 2M hydrochloric acid and then frozen until analysis.

Chemical analysis

Seventeen drug residues in the samples were measured using a previously validated analytical method (15, 16, 20). In brief, the wastewater samples were filtered and spiked with deuterated chemical standards for correcting potential instrumental variability and matrix effects during analysis. Concentrations of the drug residues in the samples were identified and quantified using liquid chromatography coupled with tandem mass spectrometry.

Back-calculation

To obtain the daily mass load (mg/day) of the drug residues in the samples, the measured concentration (µg/L) of the drug residues was multiplied by the daily wastewater flow volume (ML/day). The estimated mass load of the drug residues was normalised to the catchment population size so as to allow comparison of data (mg/day/1000 people) between the two studied catchments. To further calculate the consumption of a drug, the estimated mass load of the drug residue was corrected by the average fraction of the drug residue excreted by humans (8).

Statistical analysis

The Mann Whitney test was used to assess whether there was a significant difference in the data between the two studied catchments. The statistical analysis was performed using GraphPad Prism (version 6.05, 2014).

Results

Occurrence and mass loads of drug residues

Eleven of 17 drug residues were found in the samples (Table 1). Methamphetamine, codeine, morphine, methadone and EDDP were detected with high frequency (80–100%), followed by amphetamine (~60%), MDMA (~7%, i.e. eight occasions), and methylone, a common ecstasy substitute compound (on only three occasions). Cocaine and benzoylecgonine were detected in the WWTP-A only. The banned synthetic cannabinoid (JWH-018) was also detected on only one day in WWTP-A. No MDEA, MDA, ketamine, norketamine, mephedrone and JWH 073 were found in any of the samples. Similar patterns of the mass load of the drug residues were observed in the two studied catchments, in which methamphetamine and codeine were the most abundant, followed by morphine, EDDP, methadone and amphetamine, whereas cocaine, benzoylecgonine and MDMA were found in relatively small mass loads (Table 1).

Overall levels of consumption

Overall, a mean of 1500 milligrams of codeine was estimated to have been consumed per day per 1000 people (Table 2). An overall mean of 360 milligrams of methamphetamine and 60 milligrams of MDMA was estimated to have been consumed per day per 1000 people. Cocaine consumption was only detected at WWTP-A and only on eight occasions at a very low level (30.3 mg/day/1000 people). The overall average consumption of methadone was estimated at 38 mg/day/1000 people.

WWTP-A vs. WWTP-B consumption levels

WWTP-B catchment had slightly higher average consumption levels estimated than the WWTP-A catchment of methamphetamine (377 *vs.* 351 mg/day/1000 people, p=0.0270) and codeine (1900 *vs.* 1250 mg/per day/per 1000 people, p<0.0001). WWTP-B catchment also showed higher estimated levels than the WWTP-A catchment of MDMA (66.2 vs. 50.0 mg/per day/per 1000 people) and methadone (40.8 *vs.* 36.3 mg/per day/per 1000 people).

Drug use through the week

MDMA and methylone were only detected on the weekends (Figure 1A). The use of amphetamine and methamphetamine was evenly distributed through the week. The mass loads of morphine, codeine

and other opioids were also found consistently throughout the week (Figure 1B). Two weekday samples (1 Wednesday and 1 Thursday) identified cocaine but not its metabolite, suggesting the disposal of raw cocaine into the sewer rather than cocaine consumption. All the other detections of cocaine and its metabolite, benzoylecgonine, were found on the weekends only.

Discussion

Methamphetamine consumption was found at fairly similar levels between the two study catchments. Cocaine consumption was very low, and this is consistent with the very low use and availability of cocaine as self-reported in New Zealand social surveys of drug use (3,4). Previous national drug surveys and drug monitoring studies have suggested higher levels of 'ecstasy' use and availability than cocaine in New Zealand (3,4), but these questions refer to the street term 'ecstasy' rather the specific chemical compound, MDMA, which is detected in the wastewater analysis. It is known that the global supply of MDMA was greatly disrupted after 2008 and this resulted in the use of a range of substitute compounds in 'ecstasy' such as methylone and MEC (3).

MDMA, and the ecstasy substitute methylone, were only detected on weekends and this is consistent with the association of these drugs with late night partying which largely occurs on weekends. In contrast, amphetamine and methamphetamine were used fairly evenly across the days of the week, suggesting use is not limited to late night weekend partying. The stimulant properties of methamphetamine have long been known to have utility for a range of work activities which require long periods of stamina and concentration including truck driving, construction, hospitality and housework (3,4). Methamphetamine is also associated with high levels of dependency which may also dictate more regular use patterns (3,4). The consumption patterns for methamphetamine through the week resembled those of morphine and the other opioids, which are associated with high levels of dependency.

The synthetic cannabinoid JWH-018 was detected on one occasion but the direct injection method used for the analysis of this compound has a relatively high limit for detection. JWH-018 was banned in New Zealand in November 2012 (via a Temporary Class Drug Notice) so the finding indicates black market supply. The analytical methods required to detect more recently available cannabinoids, continue to be developed.

Limitations

The limitations of wastewater analysis have been discussed in detail elsewhere (8,11). Calculations assume the use of a single substance and an 'average' metabolism time for each drug under investigation (i.e. chronic users may show different metabolisation). The estimates of consumption per 1000 people are calculated using data on the typical dose. Typical dose can vary depending on the type of user (occasional *vs* chronic) and the route of administration (8). Additionally, conversion between the mass of a substance quantified in wastewater to the number of doses consumed is complicated by variations in drug purity in specific localities over time. Specific to this study, there were some gaps in the days of sampling for WTTP-B in particular. Due to the limited funds available for this pilot study our sampling was essentially part of the routine sampling completed at each facility. While this missing data is likely to produce some bias it should be noted that Sunday samples often produce the highest drug consumption results as they represent Saturday night partying.

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