Trends & issues in crime and criminal justice

Australian Government
Australian Institute of Criminology

No. 442 June 2012

Measuring drug use patterns in Queensland through wastewater analysis

Jeremy Prichard, Foon Yin Lai, Paul Kirkbride, Raimondo Bruno, Christoph Ort, Steve Carter, Wayne Hall, Coral Gartner, Phong K Thai and Jochen F Mueller

Foreword | *Estimating the use of illicit drugs in the general community is an important task with ramifications for law enforcement agencies, as well as health portfolios. Australia has four ongoing drug monitoring systems, including the AIC's DUMA program, the National Drug Strategy Household Survey, the Illicit Drug Reporting System and the Ecstasy and Related Drug Reporting System. The systems vary in methods, but broadly they are reliant upon self-report data and may be subject to selection biases. The present study employed a completely different method. By chemically analysing sewerage water, the study produced daily estimates of consumption of methamphetamine, MDMA and cocaine. Samples were collected in November 2009 and November 2010 from a municipality in Queensland, with an population of over 150,000 people. Estimates were made of the average daily dose and average daily street value per 1,000 people. On the basis of estimated dose and price, the methamphetamine market appeared considerably stronger than either MDMA or cocaine. This paper explains the strengths and weaknesses of wastewater analysis. It considers the potential value of wastewater analysis in measuring net consumption of illicit drugs and the effectiveness of law enforcement agency strategies.*

Adam Tomison
Director

Illicit drug use results in considerable social and economic costs to Australia (Collins & Lapsley 2008) but the magnitude of use is inherently difficult to measure. Besides being a clandestine behaviour, drug use in the community is not static and can peak at certain events (such as music festivals; Hesse, Tutenges & Schliewe 2010) or celebratory times of the year (such as New Year Eve; van Nuijs et al. 2011). Drug trends are triangulated across monitoring systems that employ different research methods and a mix of strengths with respect to, among other things, timeliness, reliability, drug-specificity and sample size (see Griffith & Mounteney 2010).

Metrics regarding the illicit drug market are relevant to the Australian Government's National Drug Strategy 2010–2015 (MCDS 2011). The quantity of drugs consumed by users reflects the total Australian supply minus that intercepted by law enforcement agencies at borders and within the country. It is possible that drug consumption may increase despite increased interception if the total Australian supply increases by a greater amount and the market takes advantage of the net increase in supply. Quantitative law enforcement seizure data are readily obtained from publications such as those provided by the Australian Crime Commission (ACC 2011). A range of monitoring instruments (a number of which are described in this article) are also able to indicate long term trends and preferences in consumption; however, measures of the total quantity of drugs consumed in a community are as yet unavailable. This article describes a way of collecting these consumption data.

A key monitoring system in Australia is the National Drug Strategy Household Survey (NDSHS), which interviews over 25,000 participants (aged 14 years or older) and is conducted every three years (AIHW 2011). The NDSHS is Australia's leading indicator of the prevalence of illicit drug use in the community. Although the NDSHS is expensive and possibly underestimates the true use by the general population of illicit drugs, such as heroin and cocaine, it nevertheless provides a valuable indication of the relative prevalence of the use of different drugs as well as binge drinking (Hall & Degenhardt 2009).

The Illicit Drug Reporting System (IDRS) collates information from a variety of sources, including drug-related arrest and seizure data, hospital data and interviews with injecting drug users, as well as key experts from health and law enforcement agencies (Stafford & Burns 2011). Comparatively inexpensive, the particular strength of the IDRS has been to monitor national trends in the use of injectable illicit drugs, including heroin, cocaine and methamphetamine (Hall & Degenhardt 2009). The Ecstasy and Related Drug Reporting System (EDRS) augments the IDRS by interviewing frequent consumers of ecstasy (3,4-methylenedioxymethamphetamine, MDMA), who provide richer data regarding substances sometimes classified as 'club drugs' such as MDMA and GHB (gamma-hydroxybutyric acid; Black et al. 2008). Finally, the Drug Use Monitoring in Australia (DUMA) program monitors drug use by arrestees through quarterly urinalysis and survey data in six Australian jurisdictions (Gaffney et al. 2010). DUMA plays a critical role in monitoring harms that impact the community through the drug-crime nexus.

Due to its focus on the general population, NDSHS necessarily reports lower rates of drug use compared with IDRS, EDRS and DUMA. The systems also differ regarding the relative prevalence or 'ranking' of the major drug types as presented in Table 1, reflecting the particular focus of the sampling in each study.

Table 1 shows the predominance of cannabis. Methamphetamine use appears relatively high among the special cohorts, but lower than MDMA in NDSHS. Cocaine use is ranked second last or last across all monitoring systems. It is possible that this represents an underestimation of the true extent of cocaine use in the community. Urinalysis may under-represent cocaine use because of the rate at which it is excreted by the body; the DUMA authors suggest that the self-reported rate of cocaine use of three to four percent may be a more reliable estimate (Gaffney et al. 2010; see further Melis, Castiglioni & Zuccato 2011). More generally, Dunn et al. (2011) have suggested that, while current monitoring systems reach both lower-middle, socioeconomic recreational polydrug users (young, club drug users) and those who inject cocaine, they do not reach a third important group, namely those cocaine users who occupy the higher end of the socioeconomic scale. As well as apparently being reluctant to participate in surveys, this group is not well represented in police detainee samples and is unlikely to present to public treatment services where cocaine-related harm might be recorded.

Table 1 Rates of illicit drug use recorded by drug monitoring systems

	National Drug Strategy Household Survey 2010	Illicit Drug Reporting System 2010	Ecstasy & Related Drug Reporting System 2010	Drug Use Monitoring Australia 2008
	General population, 14+	People who regularly inject drugs	Regular consumers of MDMA	People detained by police
	% used last 12 months (n=26,648)	% used last 6 months (n=902)	% used last 6 months (n=693)	% urinalyses 2008 (n=3,101)
Cannabis	10.3	75	80	48
MDMA	3.0	14	100[a]	3
Methamphetamine[b]	2.1	60	56	21
Cocaine	2.1	18	48	1
Heroin	0.2	64	4	11

a: Since MDMA use is required for participation in EDRS studies, its use appears as 100%

b: While DUMA reports on use of 'amphetamine' and 'amphetamine-type substance' (Gaffney et al. 2010: 14), this is practically equivalent to methamphetamine, due to the almost exclusive use of the latter in Australia (ACC 2010)

Note: *Regular* means injection/use of a drug 6 or more times in the last 6 months

Sources: AIHW (2011); Gaffney et al. (2010); Sindicich and Burns (2011); Stafford and Burns (2011)

National data relating to the number and size (weight) of illicit drug seizures provide important indicators of market activity. However, drug seizure and arrest data are influenced by the activities and policies of drug law enforcement agencies; for example, an increase in resources directed at drug seizures will result in an increase in drug seizures (Willis, Anderson & Homel 2011). Data on seizures are also difficult to interpret from a law enforcement perspective. For example, a low seizure rate may indicate success because it reflects reduced drug market activity, or it may indicate failure because agencies have not been able to detect drug trafficking.

Between 2001–02 and 2008–09, in terms of both number and weight of seizures, the most prevalent drugs were cannabis (Δ9-tetrahydrocannibinol, THC), then amphetamine-type substances (ATS), other and unknown drugs, heroin and other opioids, and lastly cocaine (ACC 2010). Unfortunately, seizure data do not differentiate between methamphetamine and MDMA, which are both included in the ATS category. Anecdotal evidence from Australian forensic laboratories indicates that methamphetamine is far more prevalent than MDMA (Quinn 2009).

Wastewater analysis

Chemists can now quantify a wide variety of substances in wastewater (ie sewage) including those associated with illicit drug consumption (van Nuijs et al. 2010). The method has been used to measure drug use in Europe, North America and Australia (Irvine et al. 2011; Lai et al. 2011) and to compare drug use across different cities and time periods (Zuccato et al. 2011). This paper demonstrates how recent advances in analytical chemistry can assist with measuring drug use in the Australian community.

Unlike the drug monitoring systems outlined above that provide person-centric data, wastewater analysis (WWA) is population-based and cannot provide person level information on individuals' drug consumption, including frequency of use or polydrug use.

However, WWA can efficiently provide reliable, objective chemical data on the use of methamphetamine, MDMA and cocaine—drugs of major concern to the community—in both small and very large population groups (potentially hundreds of thousands of people). The analyses may also be conducted at a high frequency to give, for instance, daily readings. This method circumvents the difficulties involved in accessing high socioeconomic cocaine users. It also avoids one problem regarding self-reported substance use that is particularly relevant to use of tablets sold as MDMA. Deceptive trade practices in the illicit drug market mean that methamphetamine or other substances are substituted in tablets purporting to contain MDMA (Parrott 2004). Whereas self-report studies reflect users' belief regarding substance use, WWA (similar to DUMA) provides objective data that accurately differentiates between drugs such as methamphetamine and MDMA. Finally, WWA data are not subject to changes in the activities and policies of drug law enforcement agencies in the same ways as drug seizure and arrest data.

This paper presents findings from a national team (see Lai et al. 2011), who sampled a wastewater treatment plant in a major municipality of Queensland, with a population of over 150,000 people (the actual figure from local government records. is withheld) The objectives of the research were to compare Australian drug monitoring systems with wastewater data sampled over two time points in 2009 and 2010. For the reasons outlined below, the analyses excluded cannabis and heroin and instead focused on methamphetamine, cocaine and MDMA.

What does WWA measure?

When an illicit drug is consumed it passes into the bloodstream, exerts its affect upon the body and is then excreted in urine, faeces, saliva and sweat. The process of excretion occurs even when illicit drugs are administered via different methods—injecting, smoking, snorting, swallowing and so forth. Most drugs are excreted within a few hours with the exception of THC (see Baselt 2008).

Among the chemicals excreted is the unchanged or 'parent' drug. Most drugs also undergo metabolism, some form of alteration as a result of action by the body's enzymes (usually in the liver). The altered products are called *metabolites*. Like their parent drugs, metabolites are also excreted in urine, faeces etc. Individuals vary in their capacity to metabolise drugs, which results in individual differences in the parent drug and metabolite content of urine. It is nonetheless defensible to use average human excretion values for each drug. If the population contributing to a wastewater sample is large, then one can reasonably expect that the population's metabolic performance is less variable than that of an individual.

In this and similar studies (Zuccato & Castiglioni 2011), the investigative strategy is to use chemical analysis to quantify the levels of parent drugs and metabolites in wastewater samples. These levels and the average excretion values are used to back-calculate the estimated total consumption of particular drugs in the population that were found in the wastewater. In this article, the levels of parent drugs and metabolites in the wastewater are referred to as the 'loadings' of those compounds. It is important to recognise that the back-calculated amounts represent the weight of the drugs' active ingredient that has been consumed, not the weight of drug powder that has been consumed. This is because drugs are usually diluted with varying quantities of 'cutting' agents, such as sugar or glucose. Care must therefore be taken when attempting to compare the weights of drugs reported here and in other WWA studies with street seizure weight data such as those reported in IDRS.

Cocaine estimation

The urine of an individual who has consumed cocaine will contain cocaine and its metabolite, benzoylecgonine (BE) (see Baselt 2008). Back-calculations for most drugs are subject to some uncertainty as indicated in the following sections (Khan & Nicell 2011; Lai et al. 2011). However, back-calculating cocaine involves less uncertainty largely due to the fact that neither cocaine nor BE are produced by consumption of other drugs or environmental sources (Khan & Nicell 2011).

Methylamphetamine (methamphetamine) estimation

One of the major metabolites of methamphetamine is amphetamine. The urine of a person who has consumed methamphetamine will therefore contain both methamphetamine and amphetamine (Baselt 2008). Two factors can produce unreliability when back-calculating the rate of consumption of methamphetamine through WWA. First, methamphetamine is also a metabolite of selegiline (a drug used to treat Parkinson's disease). Therefore, the legal use of selegiline will inflate the apparent rate of methamphetamine consumption. Fortunately, the known usage of selegiline in Australia is small so its contribution to the wastewater load of methamphetamine is likely to be negligible (Hollingworth, Rush, Hall & Eadie 2011; Irvine et al. 2010).

Second, amphetamine in wastewater can arise as a result of the legal usage of dexamphetamine (a drug prescribed primarily to treat attention deficit hyperactivity disorder), the illegal consumption of amphetamine as well as the illegal consumption of methamphetamine. Back-calculation of methamphetamine consumption from loadings of amphetamine will therefore overestimate the consumption of methamphetamine. However, in Australia amphetamine is rarely found in police drug seizures or produced in clandestine laboratories (ACC 2011); therefore, this source of amphetamine in wastewater can be ignored for practical purposes.

In order to maximize the accuracy of the back-calculations, this study used Queensland prescription data from the Pharmaceutical Benefit Scheme (PBS) to subtract contributions from both selegiline and dexamphetamine usage (Hollingworth et al. 2011a, 2011b).

MDMA estimation

Similar uncertainties affect estimates of consumption of MDMA. Following consumption of MDMA, the user's urine will contain both MDMA and metabolites, including MDA (3,4-methylenedioxyamphetamine), which is itself an illicit drug and also a metabolite of MDEA (3,4-methylenedioxy-N-ethylamphetamine). For these reasons, loadings of MDA are not typically used to back-calculate use of MDMA.

Heroin estimation

Heroin is metabolised so rapidly that it is rarely found in urine. Its metabolite, morphine, is usually found. Estimation of the rate of consumption of heroin from WWA is difficult because morphine in wastewater can arise from consumption of pharmaceutical morphine and codeine, as well as heroin. Since codeine can be purchased without a prescription, total codeine consumption figures are not available at the level of accuracy required to allow back-calculation of heroin consumption through WWA.

THC estimation

Although the loading of THC-acid (a metabolite of THC, the active ingredient in cannabis products) was measured in wastewater by the present study, these data are not presented here. Laboratory tests indicate that the current analytical method used in this study and in other laboratories substantially under-represents the loading of THC-acid and produces inaccurate estimates of THC consumption. This is because THC-acid tends to bind with solids/particulates and so is not available for analysis in the water phase (Khan & Nicell 2011).

Benefits of measuring both parent drugs and metabolites

The fact that both parent drug and metabolite can be measured in wastewater offers opportunities for quality assurance in measuring illicit drug consumption in the population. For example, with cocaine the rate of consumption in a community can be estimated from either the measured cocaine parent in wastewater or from the measured BE value. In this study, good agreement was found between the two estimates, thereby verifying their reliability. In this Trends & Issues paper, for methamphetamine and cocaine consumption figures, average consumption values calculated from both the parent drug and metabolite loadings are reported.

Calculating doses from loadings

The loadings within the population have been converted to the estimated number of doses consumed per capita. For this purpose, the assumption has been made that a typical dose of illicit methamphetamine is between 20mg (P Pigou, Forensic Science SA, South Australian Attorney-General's Department, personal communication 5 September 2011) and 41mg—based on median consumption amounts reported in survey studies from Queensland (Sindicich & Burns 2011, 2010) and purity of analysed seizures from Queensland (ACC 2011, 2010) in the same year (see Table 3). It has also been assumed that a typical dose of cocaine is 140–150mg (Sindicich & Burns 2011, 2010; ACC 2011, 2010) and MDMA is 60–100mg, based on data from Victoria Police Forensic Services Department (Quinn 2009).

Population

In order to calculate per capita usage, an accurate measure of the population of the wastewater catchment is needed. Local government statistics on the number of residents within a geographical region do not take into account the number of visitors or absentees. Local government statistics on the catchment population in this study are withheld. The figure is over 150,000 people.

Dumping illicit drugs in sewers

Illicit drugs are sometimes flushed down sewers to avoid detection by police. Wastewater analysis cannot chemically distinguish between dumped drugs and parent drugs that have been consumed and excreted. However, the high value of illicit drugs makes it improbable that dumping would occur on a large enough scale to affect estimates. Additionally, the good agreement found in the present study between the parent drugs and metabolites of both cocaine and methamphetamine indicates that dumping is not a significant issue. If it were, the metabolite loadings would be appreciably lower than the parent drug loadings.

Method

Raw wastewater samples were collected at the inlet of a sewage treatment plant (STP) that receives wastewater from a catchment in Queensland with a population of over 150,000 persons. Two sampling campaigns obtained daily composite samples for:

- 20 November—1 December 2009 (12 days); and
- 11—25 November 2010 (15 days).

A continuous flow proportional sampling mode was used to collect representative 24 hour composited wastewater samples (Ort et al. 2010). Samples were refrigerated at 4oC during collection, preserved using 2M hydrochloric acid on site, transported with ice and stored in darkness at -20oC until analysis. Samples were collected at 6:00 am each day.

Using a validated analytical method (Lai et al. 2011), the concentrations of cocaine, BE, amphetamine, methamphetamine and MDMA were measured in the samples. Generally, acidified wastewater samples were spiked with isotopically-labelled drugs as internal standards. Target chemicals in the samples were pre-concentrated by solid phase extraction cartridges (mixed cation-exchange) and then eluted as extracts that were analysed by liquid chromatography, coupled with tandem mass spectrometry.

The back-calculation method employed in the literature (eg Zuccato et al. 2008, 2011) was applied. Briefly, daily mass loadings (mg/day) of chemicals were estimated by multiplying chemical concentrations (ug/L) measured in samples with the daily flow rate (L/day) of the wastewater. Mass loadings were then converted to masses of drugs consumed using the excretion fractions of the parent drug and/or metabolite. After normalisation to the catchment population, the figures of per capita chemical consumption (mg/day/1,000 people) were arrived at. The daily doses consumed per capita (doses/day/1,000 people) were back-estimated using typical dose (mg) values for each particular drug.

Non-parametric Kolmogorov-Smirnov tests were used to assess changes in estimated drug consumption patterns between the 2009 and 2010 sampling periods. Pearson correlation analysis was used to assess correlations between concentrations of parent drugs and metabolites. The statistical analyses were conducted with SPSS and SigmaStat software (Version 3.5).

Results

Table 2 presents the estimated milligrams per day per 1,000 people for cocaine, methamphetamine and MDMA.

Table 2 indicates that the recorded levels of all drugs varied daily over the 12 days of sampling in 2009 and the 15 days in 2010. Increased quantities of methamphetamine, cocaine and ecstasy were detected on Saturdays and Sundays. As samples were collected at 6.00 am each day, this likely reflects consumption on Friday and

Saturday nights. There were also notable changes in the levels of drugs identified in the two sampling periods. The average loading per 1,000 people of cocaine in 2009 (221mg, SD=100) was more than four times that seen in 2010 (52mg, SD=21); a significant decline—Kolmogorov-Smirnov Z=2.58, $p<0.001$. Conversely, loadings of methamphetamine increased between 2009 (158mg, SD=40) and 2010 (228mg, SD=40)—Kolmogorov-Smirnov Z=1.81, $p=0.003$. No changes were apparent in mean MDMA loadings between 2009 (131mg, SD=62) and 2010 (139mg, SD=125)—Kolmogorov-Smirnov Z=0.99, $p=0.213$. Daily loadings are displayed in Figure 1, which presents each drug type by each sampling year (mg/day/1,000 people).

Table 3 presents the mean of the loadings per 1,000 people for the three drug types in each year. It also presents estimated doses per 1,000 people and the corresponding estimated street value.

Table 2 Daily consumption (mg/day/1,000 people^) of illicit drugs in the catchment November 2009 and 2010

2009	Cocaine[a]	Methamphetamine[b]	MDMA
Friday 20/11	188	207	66
Saturday 21/11	297	183	105
Sunday 22/11	421	240	254
Monday 23/11	203	123	142
Tuesday 24/11	148	145	127
Wednesday 25/11	122	113	91
Thursday 26/11	143	125	84
Friday 27/11	159	117	78
Saturday 28/11	275	155	124
Sunday 29/11	293	168	178
Monday 30/11	196	132	139
Tuesday 1/12	203	189	179
Mean mg	221	158	131
2010	**Cocaine[a]**	**Methamphetamine[b]**	**MDMA**
Thursday 11/11	52	204	56
Friday 12/11	54	197	45
Saturday 13/11	79	240	127
Sunday 14/11	80	275	363
Monday 15/11	58	235	208
Tuesday 16/11	34	211	98
Wednesday 17/11	32	194	56
Thursday 18/11	35	199	47
Friday 19/11	44	213	50
Saturday 20/11	68	271	134
Sunday 21/11	79	304	350
Monday 22/11	62	277	252
Tuesday 23/11	43	247	150
Wednesday 24/11	30	176	74
Thursday 25/11	27	178	74
Mean mg	52	228	139

a: Average of back-calculations from cocaine (parent drug) and metabolite (benzoylecgonine)

b: Average of back-calculations from methamphetamine (parent drug) and metabolite (amphetamine)

Table 3 takes into account the fact that standard drug doses differ for methamphetamine and MDMA. Additionally, the estimates of standard drug doses for all three substances changed between 2009 and 2010, as did estimates of the cost of a standard dose. The mean number of doses per 1,000 people per day was calculated by dividing the mean mg/1,000 people—derived from WWA—by the standard dose estimates. Multiplying these figures by the cost per dose gives the estimated mean street value of each drug per 1,000 people per day.

For example, in the 12 days of sampling in 2009, it was estimated that an average of 158mg of methamphetamine was used per 1,000 people. Using the upper estimate of 41mg per dose, this translated to an average of 3.9 doses per day per 1,000 people. Multiplying this by $90 indicates that over the sampling period an average of $347 was spent on methamphetamine each day for every 1,000 people in the catchment.

Importantly, Table 3 illustrates that after standard doses were taken into account, the most commonly consumed drug was methamphetamine in both years. Even on the basis of a 41mg standard dose, methamphetamine use during the 2009 sampling period was higher than MDMA and cocaine. In 2010, methamphetamine use was 2.9–8.1 times higher than MDMA and 22–38 times higher than cocaine.

In terms of estimated daily street value, cocaine ($237 per 1,000) was comparable to methamphetamine ($347–711 per 1,000) in 2009. But in 2010, estimated expenditure on methamphetamine was many times greater than the other two substances.

Discussion

This study covered a limited geographical range, a limited number of drugs and collected data at only two points in time—both of which are celebratory periods for many young people when drug use might be expected to increase (November 2009 and 2010). The study provided no information on individuals' patterns of drug

Table 3 Drug type by mean mg per 1,000 people, estimated doses per 1,000 people and estimated street value per 1,000 people (November 2009 and November 2010)

Drug type	Mean mg/1,000 people estimated from WWA	Standard drug dose mg[a]	Mean doses per 1,000 people per day	Cost per dose Queensland ($AUD)[b]	Estimated street value per 1,000 people per day ($AUD)
2009					
Methamphetamine (low dose)	158	20	7.9	90	711
Methamphetamine (high dose)	158	41	3.9	90	347
MDMA (low dose)	131	60	2.2	20	44
MDMA (high dose)	131	100	1.3	20	26
Cocaine	221	140	1.6	150	237
2010					
Methamphetamine (low dose)	228	20	11.4	100	1,140
Methamphetamine (high dose)	228	34	6.7	100	671
MDMA (low dose)	139	60	2.3	25	58
MDMA (high dose)	139	100	1.4	25	35
Cocaine	52	150	0.3	150	52

a: Methamphetamine standard dose ranges: 20mg (P Pigou, Forensic Science SA, South Australian Attorney-General's Department, personal communication 5 September 2011), 34–41mg (based on median typical dose consumed by EDRS respondents in Queensland (Stafford & Burns 2011, 2010) multiplied by mean purity of Queensland police seizures from the same period (ACC 2011, 2010)). The extremes of these 2 estimates are displayed in the Table. Cocaine standard dose ranges: 140–150mg (as per estimating procedures for methamphetamine). MDMA standard dose ranges: 60–100mg (based on typical contents of a typical single tablet from Victoria Police Forensic Services analysis—Quinn 2009).

b: EDRS Queensland median prices for typical dosages (Stafford & Burns 2011, 2010)

use. Nevertheless, the study produced interesting findings concerning a very large population. The findings were not subject to sampling selection biases that may arise from low participation rates or under-reporting of drug use in surveys. Nor were they likely to be affected by drug law enforcement agency activity in the same way as are drug seizure and arrest data.

The loading data spiked on weekends. Since samples were collected at 6:00 am, this probably reflects an increase in drug consumption on Fridays and Saturdays. More important, the load data also indicate a statistically significant decline in cocaine levels between 2009 and 2010. The reverse pattern was found for methamphetamine—a statistically significant increase in methamphetamine use between 2009 and 2010. This suggests that these two drugs may be economic substitutes for each other. The interrelationship could be explored further in the Australian context in surveys, with geographically defined information on price, purity and supply. The current findings are broadly similar to Zuccato et al.'s (2011) European study inasmuch as they detect fluctuations over time, differing between drug types.

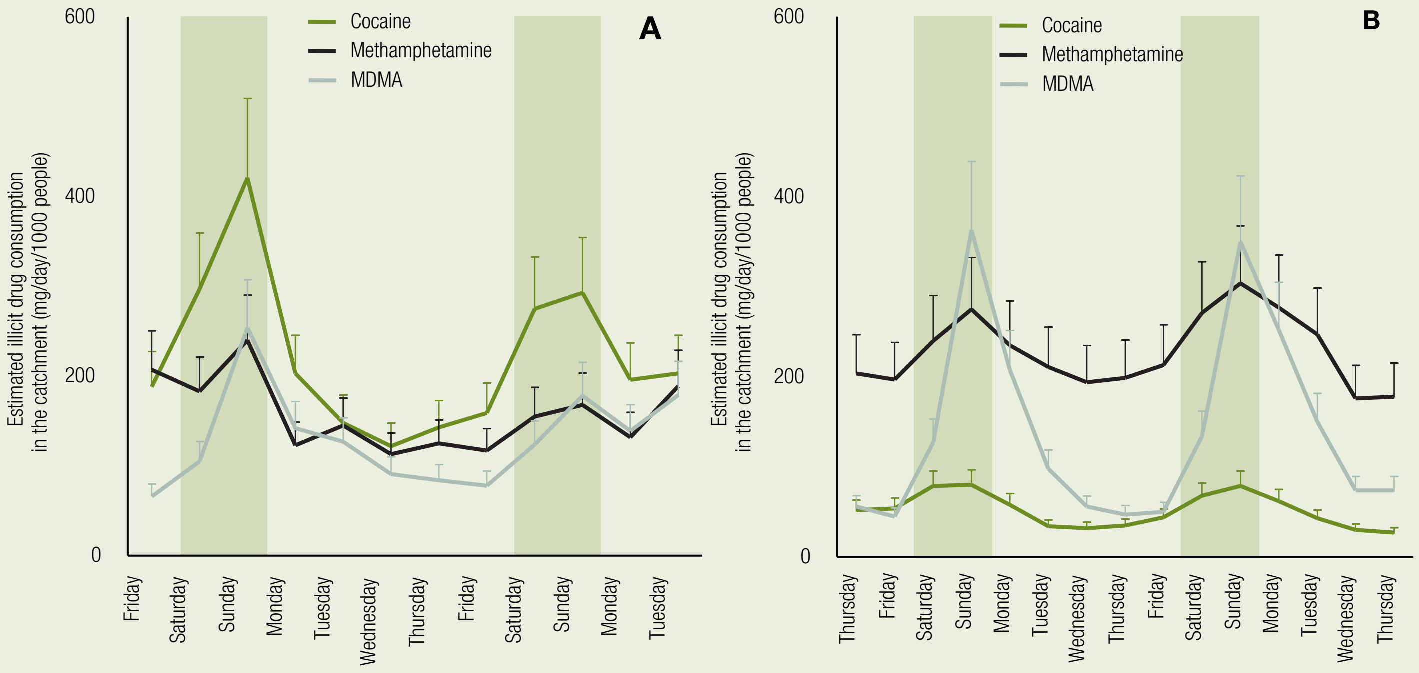
It is suggested that estimating numbers of doses per 1,000 people is valuable, despite the uncertainties involved. This is because it is only after doses are calculated that the scale of the methamphetamine market and its full cash value can be estimated. The dose data indicate that during the two periods of sampling, consumption of methamphetamine was greater than either MDMA or cocaine, especially in 2010. These results are consistent with findings from other studies regarding the frequency of use. Among NDSHS participants, daily or weekly use of methamphetamine was reported more commonly than daily or weekly use of MDMA or cocaine (AIHW 2011). The current data are also consistent with IDRS and DUMA (see Table 1), which both report that methamphetamine use is considerably higher than either MDMA or cocaine (among injecting drug users and arrestees respectively).

The findings regarding the drop in cocaine use from 2009–10 differ from other studies. The IDRS reported cocaine use to be stable across 2008–09 nationally (Stafford & Burns 2011). A national increase in cocaine use was reported in both the EDRS (2009–10) (Sindicich & Burns 2011) and the NDSHS (2007–10) (AIHW 2011). It is difficult to reconcile these findings. Since the data concern a particular region of Queensland and small time periods—12 days and 15 days respectively in 2009–10—it may be that irregular fluctuations in the cocaine market were detected. Arguably, WWA has greater capacity to detect such fluctuations because of its high temporal resolution; WWA in this study involved daily data points. By contrast, IDRS asks participants to report on the previous six months of drug use and for NDSHS, the time frame is 12 months. In addition, as noted, WWA is not likely to be subject to some of the problems associated with reaching certain types of cocaine users, unlike NDSHS, EDRS and IDRS (Dunn et al. 2011). Finally, the sample size was very large (over 150,000 people) and is several times larger than the samples sizes of NDSHS, EDRS and IDRS combined. The authors concur with the findings of the Crime and Misconduct Commission that the Queensland cocaine market deserves close monitoring (CMC 2010).

This study has demonstrated that WWA has potential to usefully supplement information gathered by current drug monitoring systems. By producing time sensitive, chemical data from large populations, the WWA method provides detailed but anonymous information on the size and evolution of drug markets. Future WWA studies could contribute to the evidence base for the National Drug Strategy 2010–2015 by sampling over longer time periods and comparing findings from catchments in different regions within and between jurisdictions. This may be the best way of assessing the true size of the cocaine market and how it is affected by the strategy and actions undertaken by operational law enforcement. WWA, combined with current price data, can be used to estimate the amounts of cash that exchange hands in the drug market.

In addition to the strategic information WWA can provide, it can also be used in a tactical sense. As indicated by the data presented in this article, drug consumption can be monitored temporally (ie on a daily basis) and geographically (ie to suburbs serviced by a particular wastewater treatment plant). This offers criminal justice agencies the potential to measure the effectiveness

Figure 1 Estimated illicit drug consumption (mg/day/1,000 people) using WWA during 20/11–1/12 2009 (A) and 11/11–25/11 2010 (B), by day of the week



of particular supply reduction strategies, such as law enforcement operations. For instance, using temporally resolved WWA data, police could monitor the impacts of significant seizures on regional drug consumption. If an impact is observed, its duration, size and how quickly it commenced would highlight supply–chain dynamics and indicate the magnitude of the gap between supply and demand. Under certain circumstances, examination of disruption of drug consumption subsequent to the arrest of particular individuals or groups might shed light on the extent and relative contribution of their trafficking networks.

In time, as the efficacy of the WWA method improves, it may be considered to form a fifth arm of the Australian drug monitoring system—one which is able to measure across multiple urban and regional sites. A national longitudinal map based on WWA would address gaps in the current monitoring systems arising from sample size, frequency of data collection and reliance on self-report data. Future analysis is required to understand how such a national WWA monitoring system might also assist with a drug law enforcement performance measurement framework, as proposed by Willis, Anderson and Homel (2011). The developers of the framework argue for its need on the basis that it would, among other things, provide a rigorous evidence-base with which:

- law enforcement agencies could demonstrate and be accountable for the impact of their activities;
- long-term strategic decision making could be undertaken; and
- justifications could be formed for expending and seeking resources.

In considering the breadth of data sources that need to be incorporated into the framework (beyond seizure and arrest data), Willis, Anderson and Homel (2011:1) note that supply and use of illicit drugs ‘can only be monitored through use of indirect indicators linked to observable consequences, such as crime, drug-related illness, injury and death’. It is suggested that WWA should be included as a measure of drug consumption, primarily because WWA directly reflects observable consumption of all users.

References

All URLs correct at May 2012

Australian Crime Commission (ACC) 2011. *Illicit drug data report 2009–10*. Canberra: Australian Crime Commission

Australian Crime Commission (ACC) 2010. *Illicit drug data report 2008–09*. Canberra: Australian Crime Commission

Australian Institute of Health and Welfare (AIHW) 2011. *2010 National drug strategy household survey report*. *Drug Statistics Series* no. 25. Canberra: AIHW

Black E et al. 2008. *Australian trends in ecstasy and related drug markets 2007: Findings from the ecstasy and related drugs reporting system (EDRS)*. University of New South Wales, Sydney: National Drug and Alcohol Research Centre

Baselt RC 2008. *Disposition of toxic drugs and chemicals in man*, 8th ed. Foster City, CA: Biomedical Publications

Collins E & Lapsley H 2008. *The costs of tobacco, alcohol & illicit drug abuse in 2004/05*. Monograph series 66. Canberra: Department of Health and Ageing

Crime and Misconduct Commission (CMC) 2010. Illicit drug markets in Queensland: a strategic assessment. *Crime Bulletin Series* no. 12. Brisbane: Crime and Misconduct Commission

Dunn M, Bruno R, Burns L & Roxburgh A 2011. Effectiveness of and challenges faced by surveillance systems. *Drug Testing and Analysis* 3(9): 635–641

Gaffney A, Jones W, Sweeney J & Payne J 2010. *Drug Use Monitoring in Australia: 2008 annual report on drug use among police detainees*. Monitoring report no. 09. Canberra: Australian Institute of Criminology. http://aic.gov.au/publications/current%20series/mr/1-20/09.aspx

Griffiths P & Mounteney J 2010. Drug trend monitoring, in Miller P, Strang J & Miller P (eds). *Addiction research methods*. New Delhi: Addiction Press, Wiley-Blackwell: 337–354

Hall W & Degenhardt L 2009. The Australian Illicit Drug Reporting System: Monitoring trends in illicit drug availability, use and drug-related harm in Australia 1996–2006. *Contemporary Drug Problems* 36 (Fall/Winter): 643–661

General editor, *Trends & issues in crime and criminal justice* series:
Dr Adam M Tomison, Director, Australian Institute of Criminology

Note: *Trends & issues in crime and criminal justice* papers are peer reviewed

For a complete list and the full text of the papers in the *Trends & issues in crime and criminal justice* series, visit the AIC website at: http://www.aic.gov.au

ISSN 0817-8542 (Print)
1836-2206 (Online)

GPO Box 2944
Canberra ACT 2601, Australia
Tel: 02 6260 9200
Fax: 02 6260 9299

Hesse M, Tutenges S & Schliewe S 2010. The use of tobacco and cannabis at an international music festival. *European Addiction Research* 16: 208–212

Hollingworth S et al. 2011. Australian national trends in stimulant dispensing: 2002–2009. *Australian and New Zealand Journal of Psychiatry* (45): 332–336

Hollingworth S, Rush A, Hall W & Eadie M 2011. Utilization of anti-Parkinson drugs in Australia: 1995 to 2009. *Pharmacoepidemiology and Drug Safety* 2011b (20): 450–456

Irvine R et al. 2011. Population drug use in Australia: A wastewater analysis. *Forensic Science International* 210 (1–3): 69–73

Khan U & Nicell J 2011. Refined sewer epidemiology mass balances and their application to heroin, cocaine and ecstasy. *Environment International* 37 (7):1236–1252

Lai FY et al.2011. Refining the estimation of illicit drug consumptions from wastewater analysis: Co-analysis of prescription pharmaceuticals and uncertainty assessment. *Water Research* 45: 4437–4448

Melis M, Castiglioni S & Zuccato E 2011. Metabolism and excretion of illicit drugs in humans, in Castiglioni S & Zuccato E (eds), *Illicit drugs in the environment: Occurence, analysis, and fate using mass spectrometry*. Hoboken, NJ, USA.: John Wiley & Sons, Inc.: 29-52

Ministerial Council on Drug Strategy (MCDS) 2011. *National drug strategy 2010–2015: A framework for action on alcohol, tobacco and other drugs*. Canberra: Ministerial Council on Drug Strategy

Ort C, Lawrence M, Reungout J & Mueller JF 2010. Sampling for PPCPs in wastewater systems: A comparison of different sampling modes and optimization strategies. *Environmental Science and Technology* 44: 6289–6296

Parrott A 2004. Is ecstasy MDMA? A review of the proportion of ecstasy tablets containing MDMA, their dosage levels, and the changing perceptions of purity *Psychopharmacology* 173: 234-241

Quinn C 2009. Drug analysis: Current issues for the drug market. Paper presented at the 2009 National Drug Trends Conference, Sydney

Sindicich N. & Burns L 2010. Australian trends in ecstasy and related drug markets 2010: Findings from the ecstasy and related drugs reporting system (EDRS). *Australian Drug Trend Series* no. 46. Sydney: National Drug and Alcohol Research Centre, University of New South Wales

Sindicich N & Burns L 2011. Australian trends in ecstasy and related drug markets 2010: Findings from the ecstasy and related drugs reporting system (EDRS). *Australian Drug Trend Series* no. 64. Sydney: National Drug and Alcohol Research Centre, University of New South Wales

Stafford J & Burns L 2010. Australian drug trends 2009: Findings from the illicit drug reporting system (IDRS). *Australian Drug Trends Series* no. 37. Sydney: National Drug and Alcohol Research Centre, University of New South Wales

Stafford J & Burns L 2011. Australian drug trends 2010: Findings from the illicit drug reporting system (IDRS). *Australian Drug Trends Series* no. 55. Sydney: National Drug and Alcohol Research Centre, University of New South Wales

van Nuijs A et al. 2011. A one year investigation of the occurrence of illicit drugs in wastewater from Brussels, Belgium. *Journal of Environmental Monitoring* 13(4):1008–1016

van Nuijs A et al. 2010. Illicit drug consumption estimations derived from wastewater analysis: A critical review. *Science of the Total Environment* 409 (19): 3564–3577

Willis K, Anderson J & Homel P 2011. Measuring the effectiveness of drug law enforcement. Trends & Issues in Crime and Criminal Justice no. 406. Canberra: Australian Institute of Criminology. http://aic.gov.au/publications/current%20series/tandi/401-420/tandi406.aspx

Zuccato E et al. 2011. Changes in illicit drug consumption patterns in 2009 detected by wastewater analysis. *Drug and Alcohol Dependence* 118: 464–469

Zuccato E & Castiglioni S 2011. Assessing illicit drug consumption by wastewater analysis: History, potential, and limitations of a novel approach, in Castiglioni S, Zuccato E & Fanelli R (eds), Illicit drugs in the environment: Occurrence, analysis, and fate using mass spectrometry. Hoboken, NJ: John Wiley & Sons: 291–304

Zuccato E, Chiabrando C, Castiglioni S, Bagnati R & Fanelli R 2008. Estimating community drug abuse by wastewater analysis. Environment Health Perspective 116: 1027–1032

About the authors

Jeremy Prichard, University of Tasmania; Foon Yin Lai, University of Queensland, The National Research Centre for Environmental Toxicology (Entox); Paul Kirkbride, Australian Federal Police, Forensic and Data Centres; Raimondo Bruno, University of Tasmania; Christoph Ort, University of Queensland, Advanced Water Management Centre and Eawag, Swiss Federal Institute of Aquatic Science and Technology, Switzerland, Steve Carter, Queensland Health Forensic and Scientific Services; Wayne Hall, University of Queensland, UQ Centre for Clinical Research; Coral Gartner, University of Queensland, UQ Centre for Clinical Research; Phong K Thai, University of Queensland, The National Research Centre for Environmental Toxicology (Entox) and Bond University; Jochen F Mueller, University of Queensland, The National Research Centre for Environmental Toxicology (Entox).

Acknowledgements

This study was funded by the Australian Future Forensics Innovation Network, with contributions from: the Qld Department of Employment, Economic Development and Innovation, Qld Health Forensic and Scientific Services; and the AFP Forensic and Data Centres. The authors thank the Qld municipality that participated in this study and Mr Jake O'Brien (Entox) who assisted with the sampling.