Drug Use Monitoring in Australia (DUMA)

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Toni Makkai

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Foreword

In Australia, the use of a range of drugs for personal non-medical use is prohibited under an array of State and Federal laws. The laws are designed to prohibit the manufacture, transportation, distribution, and use of these substances under a variety of circumstances. Despite these laws, the illegal use of drugs is a significant social issue. Of particular concern to law enforcement is the extent to which other criminal activity, such as property and violent offending, is associated with illegal drug use. Empirical data on this aspect of the illicit drug market is rare and the Drug Use Monitoring in Australia (DUMA) pilot study is designed to collect information on this specific topic. An important aspect of this pilot study is the collection of urine specimens for drug testing purposes.

The DUMA program is designed to provide local law enforcement with recent data on the levels of drug use amongst all detainees, not just those arrested for a drug offence.

This paper argues that urine testing is limited in what it can tell us about drug use behaviours, but it is still an important element in monitoring recent drug use. In particular, there has been some research in the criminal justice system that suggests self-reported drug use at the time of detention by police is under-reported—urine testing overcomes this problem. The combination of both drug detection testing and self-reported behaviour is potentially a powerful research methodology to further our understanding of drugs and crime. This enhanced evidence can then be used to both improve and monitor criminal justice interventions to deal with drugs and crime within the community.

This paper provides a short overview of urine testing and the various issues associated with this procedure and its application to the (DUMA) program. This project collects urine specimens for drug detection purposes and this paper outlines the surrounding issues and controversies of urinalysis testing. Urinalysis testing is often a two-step process, involving an initial screening test and then, for some classes of drugs, a confirmatory test. Screen results cannot always distinguish the particular drug that has been consumed whereas the confirmatory test provides this information. The paper also discusses issues such as the chemical changes that occur once a drug has been ingested, cutoff levels, and concentration levels.

The initial participation rates in DUMA are encouraging. Out of 980 detainees approached in four watchhouses, 814 agreed to voluntarily answer a series of questions about their drug use and criminal activities. Of these, 565 agreed to provide a urine specimen for research purposes only. These responses suggest that with the correct protocols, trained independent interviewers, and police cooperation and support, monitoring of drug use amongst detainees for research purposes is possible.

Urine testing is seen to provide independent corroboration of drug use activity. However, this paper has indicated that urine testing, like self-report data, has limitations. These limitations need to be openly acknowledged and understood. It is in fact the combination of self-report and urine testing that makes DUMA a potentially powerful law enforcement monitoring tool.

There are currently a number of advances that will overtake urine testing. These include hair analysis, sweat patches, smart patches, saliva testing, and ion mobility spectrometers. However, at this time urine testing remains the most cost-effective drug testing technology available in Australia.

Adam Graycar
Director, Australian Institute of Criminology
March 2000

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List of Abbreviations

ADAM	Arrestee Drug Abuse Monitoring
BE	Benzoylecgonine
CV	Cutoff Value
DUF	Drug Use Forecasting
DUMA	Drug Use Monitoring in Australia
EME	Ecgonine Methyl Esther
EMIT	Enzyme Multiplied Immunoassay Technique
GLC	Gas Liquid Chromatography
GC	Gas Chromatography
HPLC	High Performance Liquid Chromatography
KIMS	"On-Line" Kinetic Interaction of Micro-Particles Test
MAM	Monoacetylmorphine
MS	Mass Spectrometry
NATA	National Association of Testing Authorities
PaLMS	Pacific Laboratory Medicine Services
TLC	Thin Layer Chromatography
PCPS	Phencyclidine

Executive Summary

This paper outlines the processes involved in one specific drug detection methodology—urine testing or urinalysis. The paper argues that different types of analysis have their advantages and disadvantages. The major advantage of urinalysis testing is it provides information on very recent drug use. More specifically, it enables researchers, in most circumstances, to objectively determine whether a person who has been recently detained by the police has recently consumed drugs. This is an important policy concern as a number of surveys of prisoners have shown that drug using offenders self-report committing disproportionately more crime than non-drug using offenders. In addition, drug dependent detainees may require police to employ new ways of handling such people where duty of care issues arise such as in the watchhouse environment.

The DUMA project collects urine specimens for drug detection purposes and this paper outlines the surrounding issues and controversies of urinalysis testing. Urinalysis testing is often a two-step process, involving an initial screening test and then, for some classes of drugs, a confirmatory test. Screen results cannot always distinguish the particular drug that has been consumed whereas the confirmatory test provides this information. The paper also discusses issues such as the chemical changes that occur once a drug has been ingested, cutoff levels, and concentration levels.

There are four possible outcomes from a drug test, the two most common being a true positive or a true negative result. In a small minority of cases, a false positive or a false negative can occur. The former is where the test detects a drug but such a drug was never consumed and the latter is where the drug has been consumed but the test fails to detect its presence.

This paper argues that urine testing is limited in what it can tell us about drug use behaviours but it is still an important element in monitoring recent drug use. In particular, there has been some research in the criminal justice system that suggests self-reported drug use at the time of detention by police is under-reported—urine testing overcomes this problem. However, it is the combination of both drug detection testing and self-reported behaviour that is potentially a powerful research methodology to further our understanding of drugs and crime. This enhanced evidence can then be used to both improve and monitor criminal justice interventions to deal with drugs and crime within the community.

Introduction

This paper provides a short overview of urine testing and the various issues associated with this procedure and its application to the Drug Use Monitoring in Australia (DUMA) program. Drug testing is widely used in the United States for a variety of purposes. In 1994 it was estimated that there were 24 million tests undertaken annually, costing approximately $US1.2 billion per year (Normand et al. 1994). By 1996, 81 per cent of the Fortune 200 companies had introduced random drug testing (Reed 1999). In Australia there does not appear to be any national estimate of the number of tests undertaken. A recent survey found that 11.5 per cent of Australian public and private sector organisations had some form of drug and alcohol testing programs in place (Hume 1995). All the indicators point to increased testing across a range of institutions and groups—to name a few, sporting groups, the military, prisons, the police, drug treatment agencies, large multinational companies, and high-risk occupations like pilots and train drivers (The Privacy Committee of New South Wales 1992).

In Australia, the use of a range of drugs for personal non-medical use is prohibited under an array of State and Federal laws. The laws are designed to prohibit the manufacture, transportation, distribution, and use of these substances under a variety of circumstances. Despite these laws, the illegal use of drugs is a significant social problem. Of particular concern to law enforcement is the extent to which other criminal activity, such as property and violent offending, is associated with illegal drug use. Empirical data on this aspect of the illicit drug market is rare and the DUMA pilot study is an attempt to collect information on this specific topic. An important aspect of this pilot study is the collection of urine specimens for drug testing purposes.

DUMA is a three-year pilot study designed to test the implementation of the equivalent United States (US) Arrestee Drug Abuse Monitoring (ADAM) program (see Makkai 1999 for further details). The United States monitoring program formally began in 1987 under the title Drug Use Forecasting (DUF). It involves voluntary interviews and collection of urine specimens from

detainees at selected watchhouses in various United States cities. These interviews are conducted over a two-week period every three months. Today, the program covers 35 cities and is being expanded to 50 sites by 2001 (National Institute of Justice 1999). Its primary purpose is to provide local law enforcement with recent data on the levels of drug use amongst all detainees, not just those arrested for a drug offence. Similar programs are being trialed or have been implemented on an ongoing basis in a number of other countries, as shown in Table 1.

As the DUMA project uses urine results as one of its key indicators of drug use, it is important that non-specialists have some grasp of the complexity of urine testing. It is not, as many believe, always straightforward and definitive. Like most medical science, it is highly contingent on a range of variables and is subject to multiple interpretations. However, even with these limitations, most of the time, in most circumstances, fairly robust and authoritative conclusions can be drawn from urine testing. This paper does not offer anything new; its purpose is to explain urinalysis testing in as clear and straightforward a way as possible. As a result, a wide range of work is brought together in one publication. Although the paper attempts to use non-scientific terms, a degree of complexity is sometimes unavoidable—plain English does not always provide appropriate synonyms for the scientific or technical terms.

Table 1: I-ADAM Participating Countries

Country	Status	Number of Sites	Funding Agency	Start Date
Australia	Active pilot	4	Commonwealth's National Illicit Drug Strategy	1999
Chile	Active ongoing	1	Ministry of Justice/Health	1998
England	Active ongoing	8	Home Office	1999
Malaysia	Active pilot	2	Office of the Prime Minister	1999
Netherlands	Active pilot	1	Ministry of Justice	1999
Scotland	Active pilot	2	Scottish Office	1999
South Africa	Active ongoing	9	Department of Arts, Culture, Science & Technology's Innovation Fund	1999
USA	Active ongoing	35	Office of Justice Programs	1986

Drug Testing Methods

Drug testing methods, other than urinalysis, include blood and hair. Table 2 provides a comparison of these three most commonly used specimens. Blood and hair tend not to be routinely used for testing for illicit drugs because of high costs, underdeveloped technology, and/or greater intrusiveness. When comparing blood and urine, the detection times in urine are significantly greater than the detection times in blood because most drugs are rapidly eliminated from blood both by the body's metabolic system and by excretion into urine (Council on Scientific Affairs 1987). As the bladder is emptied only a few times during the day, the urine becomes a reservoir of drugs and metabolites.

In recent time, there has been considerable interest in hair testing, which may provide accurate information concerning past use but cannot address the issue of drug use at the time of collection. Essentially, hair records what drugs were in the blood when the hair was made into a hair follicle (DuPont and Baumgartner 1995). Importantly, hair does not deteriorate or lose the drugs trapped in it, as does blood or urine.[1] However, some research shows that passive ingestion can result in a false positive from a hair sample.[2]

Table 2: Comparison of Commonly Used Specimens for Drug Analysis

Specimen	Ease of Collection	Stability of Drugs	Average Window of Exposure	Sample Preparation Before Analysis	Possible Adulteration
Blood	Most Invasive	Variable	Recent	Minimal	No
Urine[a]	Moderate	Stable	1–3 days	Minimal	Yes
Hair[b]	Less Invasive	Stable	7–90 days	Significant	No

[a] The window of exposure is up to 30 days for cannabis, and two weeks for benzodiazepines.
[b] The window of exposure can be up to a year; it depends on how often you get your hair cut.
Adapted from Ostrea 1999, Table 3; Dupont and Baumgartner 1995, Table 1.

1 Neither urinalysis nor hair testing are reliable methdods for detecting alcohol use (DuPont and Baumgartner 1995).

2 It also appears that African Americans are 30 to 50 times more likely to return a positive from a hair test than whites or Asians. As a result they are more susceptible to passive ingestion (Reed 1999).

Hair grows at about half an inch per month and usually a one-and-half-inch sample is required to detect drug use in the previous 90 days (DuPont and Baumgartner 1995). For a sufficient sample, it usually takes 6 days of growth.[3] Urine, on the other hand, cleans out the blood and, as a result, it contains a record of what a person has been ingesting in the recent past. Thus, urine tests can usually detect use in the previous 1 to 3 days, but not longer term use. From a policy perspective, DUMA is currently most interested in determining recent drug use amongst detainees and urinalysis is the methodology employed for the pilot study.

DUMA collects self-reports from a structured interview as well as specimens for urinalysis testing. Essentially, urinalysis measures the amount of a drug that is present in the urine. Self-report data is widely used by researchers and a considerable amount of work has validated its use in a variety of settings for a range of behaviours including drug use (Harrison 1995). As self-report data is the main method of obtaining basic empirical data on the human condition, researchers are heavily reliant on this methodology, so its validity and reliability are crucial issues. Some studies (Harrison 1995) have shown that the validity of self-report drug use data can be affected by:

- How recently the drug was used.
- Whether the questions are asked by an interviewer or self-completed by the person.
- Whether the drug is stigmatised in the general community.

However, there is general consensus amongst those who work with self-report data that it is reliable and valid in most settings, despite general scepticism amongst the lay public and policy makers. Within criminology, self-reported delinquency has been found to have both concurrent and predictive validity with official records (Farrington et al. 1996). When the interviews take place within a formal criminal justice environment, such as a watchhouse, there may be more basis to scepticism about the validity of self-report data, especially for self-reported recent drug use.[4] As the interviews with detainees take place within a potentially threatening environment to the individual, the perceived threat of sanctions and the

3 Mieczkowski and Newel (1993) reported that 17 per cent of their male sample were unable to provide hair samples because the hair was too short. Feucht, Stephens and Walker (1994) also pointed out the difficulties of obtaining hair samples where subjects have relatively short hair.

4 Bigger (1979, p. 25) cites a number of research studies that have documented that "the reliability of addicts' responses varies, and for numerous reasons users do not always tell the truth".

face-to-face interview situation may reduce respondents' willingness to self-report recent drug use; this is despite the assurances of confidentiality.

For obvious reasons, law enforcement officials are particularly sceptical about self-report data from offenders. Confirmation by some independent mechanism—in this case urinalysis—is clearly an advantage. Analysis of data collected from the US-ADAM program indicates under-reporting ranges from 11 to 60 per cent; willingness to report varies accordingly by drug, age, and perceived legal consequences (Wish and Gropper 1990). Feucht et al.'s (1994, p. 112) study of juvenile detainees concluded that "self-reports of drug use by juvenile detainees obtained in the context of a detention facility appear hopelessly unreliable". Harrison (1995) argues that the narrow window of detection for urinalysis can account for some of this discrepancy, along with recall errors, problems in the question wording and instructions, and failure to recognise or identify a drug. But even after taking these factors into consideration, Harrison was not able to fully account for the discrepancy between self-report and urinalysis data.

A study of 303 detainees (see Table 3) found that considerably fewer people self-reported drug use than tested positive using urine, while hair testing detected drug use amongst an even larger proportion of the sample (DuPont and Baumgartner 1995). However, this study was conducted in the United States, where sentencing penalties for revealing illicit drug use are far greater than Australia. In Australia, detainees may be more willing to self-report recent drug use. The data suggest that those with a serious dependency problem are more likely to test positive to both the urine and the hair test. Given that hair testing is more effective in detecting long term drug users, the DUMA results will clearly underestimate the extent of regular drug use amongst detainees (see Mieczkowksi and Newel 1993). The exception is marijuana, where each method is "approximately equally effective in identifying marijuana use" (DuPont and Baumgartner 1995, p. 74, Mieczkowksi and Newel 1993).

Table 3: Comparison of Positive Outcomes: Self-reports, Urinalysis and Hair Analysis

	Self-reported Drug Use (Percentages)		Positive Results (Percentages)	
Drug	**In Prior 48 Hours**	**In Prior 30 Days**	**Urine**	**Hair**
Cocaine	8.3	11.2	20.4	46.5
Opiates	0	1.0	1.7	8.9

Source: DuPont and Baumgartner 1995, Table 4.

In theory, there are other sources of information, such as the arrestee's official criminal justice records, that could be used to infer prior drug use history. Wish and Gropper (1990) have shown that United States arrest records fail to provide the necessary information. In terms of personal information recorded about the offender's drug use, the official files are rarely systematically kept or, if kept, are not verified by independent sources. Analysis of arrests for sale or possession of a drug is not an accurate measure of drug use prevalence; reliance on these data would grossly underestimate the number of users within the criminal justice population. It is unlikely that the Australian situation is any different. Further, criminal history data based on official arrest records will grossly underestimate the extent of drug use. Two primary reasons for this are that arrest data generally underestimates criminal activity (Coleman and Moynihan 1996) and drug arrests, in particular, are notoriously unreliable as they simply reflect policing practices (Chilvers 1998). One of the goals of DUMA is to determine whether urinalysis testing provides more reliable data on recent drug use than the traditional self-report methodology and the official record.

Drugs of Interest

DUMA screens for 6 classes of drugs—opiates, benzodiazepines, cannabis, methadone, cocaine, and sympathomimetic amines (amphetamines). Table 4 provides a description of the major drugs of interest in the study. DUMA and the US-ADAM do not test for hallucinogens as the extremely small doses of these synthetic drugs make them difficult to detect with standard laboratory tests (Wish and Gropper 1990). The UK-ADAM did screen for hallucinogens in the first phase of their pilot program. No positive results were obtained (Bennett 1998). DUMA does not test for alcohol as alcohol evaporates quickly from urine; breath testing is the most commonly used and cost-effective method for detecting alcohol intoxication (Crowe 1998, p. 41, Baselt and Cravey 1995).

Where a screen is positive for three classes of drugs—opiates, benzodiazepines, or amphetamines—a confirmatory test is performed to identify the actual component or metabolite that is present in the urine. Table 4 indicates the metabolites that are most likely to be found via urine testing. In all three classes of drugs, there are substances either available over the counter (combination codeine/paracetamol and codeine/aspirin products) or on prescription (for example, diazepam, ritaline, and dexamphetamine) that can trigger a positive result. The only drugs that are not legally available under any circumstances in Australia are heroin and methylamphetamine. However, even legally available drugs can be misused and drug testing techniques can rarely, if at all, distinguish between legitimate and illegitimate use.

Drug Metabolites

Once drugs are ingested, the body breaks down these substances. In the case of heroin (diacetylmorphine) and cocaine, the body rapidly metabolises these drugs and changes its chemical form. For example, rarely, if ever, is heroin excreted from the body as heroin (Bigger 1979, p. 26). The time that this metabolic process takes varies for different drugs. Heroin is a

Table 4: Drugs of Interest

Class of drug	Drug ingested	metabolite found in urine	length of time detected in urine (average)	Cutoff levels—initial test	Cutoff levels—confirmatory test	Availability
SYMPATHOMIMETIC AMINES	Amphetamine	Amphetamine, benzoic and hippuric acid	2–4 days	300ng/ml	300	S.8 (exclude prolintane, S.4)
	Methylamphetamine	amphetamine/methylamphetamine (ephedrine/pseudoephedrine are impurities in the illicit manufacture)	2–4 days	300ng/ml	300	
BENZODIAZEPINES				100ng/ml		
	Clonazepam	7-aminoclonazepam	2–14 days		100	S4
	Nitrazepam	7-aminonitrazepam	2–14 days		100	S3, 4
	Flunitrazepam	7-aminoflunitrazepam	2–14 days		100	S8
	Diazepam	nordiazepam, temazepam, oxazepam	2–14 days		100	S4
	Temazepam	temazepam, oxazepam	2–14 days		100	S4
	Oxazepam	oxazepam	2–14 days		100	S4
CANNABIS (THC)	Cannabis	11nor9carboxydelta9 tetrahydrocannabinol. (note: delta9 tetrahydrocannabinol is the major psychoactive ingredient)	several days to 30 days average: 2–10 days for casual users and up to 30 days for chronic users.	50ng/ml	na	S8
COCAINE	Cocaine	Benzoylecgonine (BE) ecgonine methyl esther (EME), ecgonine	cocaine parent present up to approximately 3–6 hours post dose; benzoylecgonine (BE) metabolite present for approximately 24–36 hours post dose.	300ng/ml	na	S8
OPIATES	Heroin	6-monoacetylmorphine (MAM) morphine, (codeine as an impurity of heroin)	MAM detected up to 6 hours; morphine metabolite 2–3 days. If MAM is present it indicates definite heroin use.	300ng/ml	300	NA
OPIATES	Codeine	codeine, norcodeine, morphine	2–3 days	300ng/ml	300	S2, 4

S2: Available without prescription; S3: Available only from pharmacists usually without prescription; S4: Dispensed only on a doctor's or dentists' prescription; S8: Severe restrictions and tightly regulated with prior approval from the Health Department often required; na: not applicable.

Source: John Lewis 1999 (personal communication); Jatlow 1989, Upfal 1989, AS4308-1995, 1995, Council on Scientific Affairs 1987.

semisynthetic derivative from the naturally occurring alkaloid morphine. After ingestion, heroin only persists in the brain for a few minutes as it has a half-life of approximately 3 minutes (Jatlow 1989, Hawks and Chiang 1986). "A half-life is the time unit for removing 50 per cent of the drug from the body by either metabolism or excretion" (Chiang and Hawks 1986, p. 72). It is rapidly metabolised to monoacetylmorphine (MAM) and then to morphine (Jenny 1989, White and Irvine 1999, Baselt and Cravey 1995). MAM also rapidly disappears, although not as fast as diacetylmorphine. Thus, the presence of any MAM in the urine indicates very recent use of heroin.[5] Morphine takes longer to be excreted (half-life is reported to be within the range of 1.7–4.5 hours), and may be detected 2–4 days after the last dose at the 300 ng/ml cutoff. Codeine (that is present in over the counter and prescription drugs) is also metabolised into morphine and norcodeine. It is only by examining the results from the confirmatory test that the specific metabolites are determined. Unfortunately, this is not as simple as it might first appear.

Morphine can come from the use of either heroin or codeine. The following rules of thumb apply for interpreting the urine results from a confirmatory test:

- Morphine alone indicates either clinical morphine use or illicit morphine, or heroin use.
- Both morphine and codeine present—when the codeine concentration is high and greater than that of the morphine concentration, then codeine is most likely to have been ingested; otherwise the data suggest either clinical morphine use or illicit morphine or heroin use.
- Concentrations of both morphine and codeine are low—no determination can be made as to whether codeine, clinical morphine, illicit morphine or heroin has been ingested (Hawks and Chiang 1986).

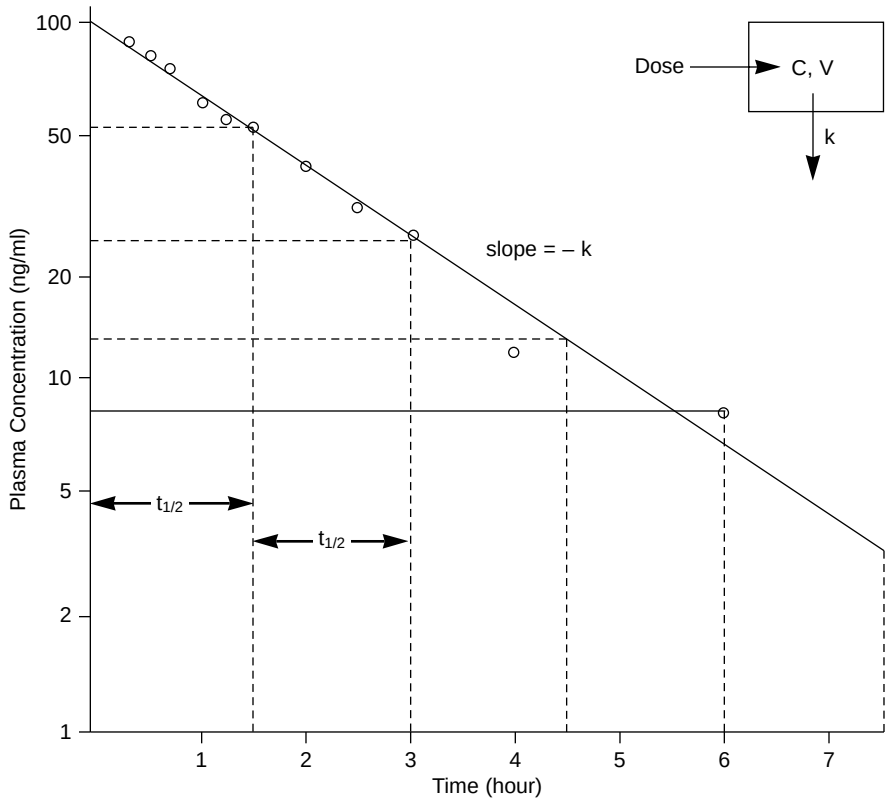
Cocaine has an elimination half-life of approximately 1.5 hours. "A five half-life period is required to eliminate approximately 97 per cent of the drug [cocaine] in the body" (Chiang and Hawk 1986, p. 72). Figure 1 shows the relationship between the concentration of a 20-mg dose of cocaine and the time it takes to be excreted from the body. The solid curve on the graph

[5] DuPont and Baumgartner (1995, p. 70) report that for opiates "90% of positive urinalysis results are overturned by medical review officers [in the United States] because of the absence of MAM or insufficient clinical evidence of drug use".

shows that 50 per cent of the drug is removed within 1.5 hours of taking the substance. It is possible that taking more of the drug results in a disproportionate increase in the amount found in the urine such that "increasing the administered dose of cocaine 2–3 times may in fact increase the blood concentration (and associated adverse effects) significantly more than 2–3 times" (Chiang and Hawks 1986, p. 75).[6]

As a result of the metabolite process in the body, drug tests are designed to identify the major metabolites of the drug in question (see Table 4) as these have a much longer half-life and are more likely to be found in the urine. For example, the cocaine metabolite benzoylecgonine (BE) has an average

Figure 1: Plasma Levels of Cocaine Following an Intravenous Dose of 20 mg Cocaine



Source: Chiang and Hawk 1986, Figure 6.

6 Considerably more research is required in this area. For example, there have not been any other reports of "non-linear" pharmacokinetics for cocaine.

urinary excretion half-life of 7.5 hours and can usually be detected up to 48 hours after a single dose, as can morphine (Preston et al. 1998, Li et al. 1998, Hawks and Chiang 1986). Table 4 indicates the approximate time for detection of the metabolites in urine.

It is important to remember that the metabolism of the drugs is affected by pharmacological factors (White and Irvine 1999) as well as chemical factors (assay sensitivity, specificity, and accuracy) (Huestis et al. 1995). This can result in the drug test detecting the metabolites in one person but not the other even though the two people have consumed the same amount of drugs over the same period of time. In addition, different laboratories can report different results for the same specimen. Only those people who have been arrested in the past 48 hours are eligible for interview in the DUMA project. Although not fool-proof, this method enables some determination to be made as to whether these drugs have been consumed within a relatively short time of the arrest.[7]

[7] Self-report data on the use of prescription and over the counter drugs as well as self-reported illegal use of substances in the three days prior to arrest will assist in this process.

Drug Testing Technology

Drug testing is divided into a two-step process—the *screening* test and then the *confirmatory* test (Council on Scientific Affairs 1987). The former test is designed to maximise the likelihood of finding a drug, while sometimes sacrificing the ability to identify the specific drug (for example, identifies opiates that could be either codeine or morphine). The test is designed to ensure that few or no people are classified as not using a drug when in fact they have (for example, false negatives). Confirmatory tests, on the other hand, are designed to ensure that positive screens are, in fact, true positives while also enabling the identification of the specific drug or metabolite in the urine. Normally a confirmatory test is only done if the screening test indicates the presence of a drug. If there is a relatively high concentration of the drug, then both the screening and confirmatory tests will be more reliable. Toxicologists report that it is difficult to detect small amounts of the drug when the tests run close to the concentration limit of what can be reliably detected (Blanke 1986, p. 44).

What is certain is that the higher the dose of drug taken, and the greater the frequency of use, the more likely it is to be detected. Although drugs are excreted at varying lengths of time, they do accumulate in the body with continued use. This effectively means that the more often the drug is used, the more likely it is to be detected. Manno notes that "a single dose of cocaine, for example, may only be detectable in urine for 1 day or less. Continued use on a daily basis may cause the drug to be detectable for 2 to 3 days after cessation of use" (1986, p. 56). In comparing hair and urine tests, Mieczkowksi and Newel (1993, p. 63) found very high concordance for cocaine when the cocaine metabolite concentrations were high. They concluded that "individuals at low concentrations (levels 1, 2, and 3) are likely to evade detection by urine, since they use either small amounts of cocaine or avoid daily or near daily use".

Screening Tests

There are two primary screening methods for detecting drugs in urine: *immunoassay* and *chromatography*. Immunoassay is the method used in the US-ADAM and DUMA projects for initial screening of illicit drugs. Essentially, the process involves using antibodies to detect the presence or absence of drugs in the urine. The specimen is compared to a calibrator, which contains a known quantity of the drug being tested. If the sample specimen is higher than, or equal to, the calibrator, then the test is considered positive. If the specimen is lower than the calibrator, then the test is considered negative. The calibrator used in the DUMA context is based on the cutoffs set by Australian Standard 4308–1995 (Standards Australia 1995). Screening tests are relative cheap and usually the turn-around time on results is very quick. The downside is that they do not tend to be as accurate as a confirmation test. An *immunoassay* commonly used in the criminal justice system is EMIT (enzyme multiplied immunoassay technique). This is the technique used by DUMA and US-ADAM. Another technique is KIMS ("On-Line" Kinetic Interaction of Micro-Particles test), used by the UK-ADAM program.

The two limitations of screening tests are *specificity* and *cross-reactivity*. Specificity refers to the extent to which the test can discriminate between different drugs (Bigger 1979). In terms of specificity, screens can only identify groups of drugs and not the specific chemical component. Thus, a positive screen for opiates cannot distinguish whether the specific chemical component is codeine or morphine. This problem is of particular concern when attempting to identify the kinds of opiates, amphetamines, and benzodiazepines an individual has been using. In comparing various methods of drug analysis, EMIT is considered to have high sensitivity and moderate specificity (Ostrea 1999, p. 42).

Cross-reactivity occurs when the test is unable to distinguish between substances that are unrelated but chemically similar. For example, poppy seeds can cause detectable concentrations of morphine or codeine, or both, in urine (Normand et al. 1994, p. 194). In addition, over the counter prescriptions can result in positive amphetamine, benzodiazepines, and opiate screens. DUMA asks participants about their use of prescription and over the counter medications in the past week. When the urinalysis results are merged with the self-report data, it will be possible to further examine self-reported prescription use versus self-reported illegal use.

Confirmatory Tests

As screening tests have less specificity and a higher likelihood of false positives, scientists recommend that positive tests be viewed as presumptive and that a positive immunoassay be retested and confirmed. The confirmation should preferably use a different technique of equal or greater sensitivity, such as gas chromatography/mass spectrometry. *Chromatography* involves separating and identifying the components of a specimen; thus, identifying the actual drug (for example, codeine rather than morphine). Chromatography methods include thin layer chromatography (TLC), gas liquid chromatography (GLC), high performance liquid chromatography (HPLC), and gas chromatography/mass spectrometry (GC/MS). GC/MS testing, although more expensive, more time consuming, and more technically complex, is recommended by AS4308–1995 and is used by DUMA. Essentially, this process involves shattering the drug into pieces that form a fragmentation spectrum. Different compounds have different fragment patterns and like fingerprints; no two are alike (Council on Scientific Affairs 1987). This spectrum of unknowns is compared to the analytic standards for those drugs and metabolites enabling identification of the compound. In comparison with various other methods of confirmatory tests, GC/MS has both high sensitivity and specificity (Ostrea 1999, p. 42). Wish and Gropper (1990, p. 343) report that "GC/MS is considered to be the absolute standard for identifying drugs" (see also Jenny 1989, p. 16).

Analysis of the accuracy of the immunoassay screening tests (see Table 5) indicate very high positive predictive values for cocaine metabolites (99.2%) and marijuana metabolites (97.8%) while amphetamines (76.8%) and opiates (70.0%) are much lower (Stuck et al. 1998, see Table 5). Given the additional cost and the high accuracy of immunoassays for marijuana and cocaine,

Table 5: Cumulative Positive Predictive Values 1993 and 1994 (Percentages)

	1993		1994	
	Positive Predictive Values	95% Confidence Interval	Positive Predictive Values	95% Confidence Interval
Amphetamines	77.7	(77.3–78.1)	76.8	(76.4–77.2)
Cocaine Metabolite	95.2	(95.0–95.4)	99.2	(99.1–99.3)
Opiates	74.6	(74.1–75.1)	70.0	(69.5–70.5)
Marijuana Metabolite	97.7	(97.6–97.8)	97.8	(97.7–97.9)

Source: Stuck et al. 1998, Table 4.

confirmatory testing has been restricted to opiates, amphetamines, and benzodiazepines.[8]

Cutoff Levels

Cutoff levels are used to determine whether a screen and the confirmatory test result is positive or negative. These levels are usually the common agreed levels at which the drug or metabolite can be detected; it is often referred to as the sensitivity level. Different testing procedures have different levels of sensitivity in detecting "a drug when it is present at greater than or equal to its predetermined analytic cutoff point" (Ostrea 1999, p. 42). For screening purposes, it is important that the test has high sensitivity so that it initially picks up recent drug use. This can result in a high false-positive rate but it also minimises the number of people who use drugs that test negative. Then in the second stage, the detected drug is confirmed using a test which has high specificity.

Jenny (1989, p. 17) suggests that there are four major criteria that are appropriate when setting the cutoff value:

1. the level should enable the detection of recent, casual drug use;
2. the level should be high enough to rule out analytical noise;
3. the level of confirmations should be lower than the screening level so as to "minimize the number of unconfirmed presumptive positive tests"; and
4. the level should be high enough to eliminate positive results from inadvertent exposure to the drug.

The point at which the cutoff level is set will influence the number of false negatives and false positives. The cutoff levels set by AS4308–1995 are designed to minimise the number of false positives so as to withstand legal scrutiny. Table 4 indicates the cutoff levels for both the screen and confirmatory tests used by DUMA.

[8] Confirmatory testing of benzodiazepines is undertaken as it provides a more accurate report on what drugs detainees are using.

Concentration Levels

Concentration is a term that refers to the amount of a drug or its metabolite in a given volume, usually nanograms per millilitres (Bigger 1979, Visher and McFadden 1991). However, screen results are normally expressed in qualitative terms of positive or negative (Wilkins 1998, p. 235) based on the agreed minimal concentration of the substance that the test can detect. For DUMA, the minimal concentration is set to AS4308–1995.[9] As urinalysis results are usually expressed in this qualitative fashion, the quantitative levels have not been traditionally used to determine the frequency and amount of use. However, in the 1990s there has been some research using quantitative urine levels of drug use, including the tracking of sequences of poly drug use (Wilkins 1998, p. 240, Preston et al. 1998, Li et al. 1998). DUMA does record the amount of drug or its metabolite in a given volume (for example, the concentration levels) for both the screen and confirmatory tests. However, in both cases the data are treated qualitatively in terms of a positive or negative.

[9] Except for benzodiazepines where a hydrolised procedure is used and the cutoff level is set to 100.

Interpretation of Results

There are four possible outcomes from a test as shown in Table 6:

1. true positive (the drug is present);
2. true negative (drug is not present);
3. false positive (drug detected but drug not present); and
4. false negative (drug not detected but drug is present).

Table 6: Outcomes from Drug Test

	Drug Use	
Test results	Yes	No
Positive	1. True positive	3. False positive
Negative	4. False negative	2. True negative

Source: Bigger 1979, p. 30.

What Does a Positive Test Result Indicate?

A positive drug test indicates that the specific drug is present in the urine at the designated cutoff level. To minimise the possibility of a person testing false positive, the cutoff concentration is set to the lowest concentration of the drug that can be reliably detected, usually at the 95 per cent confidence level (Jenny 1989, p. 17). It is important to understand that "owing to analytical variability, determination of the status of drug presence or absence is not absolute" (Jenny 1989, p. 17).

A positive test cannot determine the dosage, when the drug was administered, how it was administered, or the degree of impairment (Council on Scientific Affairs 1987, Jenny 1989, McBay 1989, Wilkins 1998). The presence of a drug only means the person has ingested the drug (and in

the case of cannabis this may be passive ingestion[10]). Although the test results from screening and confirmatory procedures present a "number" or concentration value, this number cannot be equated to levels of intoxication or performance (McBay 1989). McBay (1989, pp. 290–291) notes "Except for alcohol there is a lack of data in the literature on blood concentration and on drugs in urine upon which an expert may base an opinion of drug-related impairment or improvement … Even if a drug or metabolite in urine is positively identified and precisely quantified, there is no scientific basis for forming opinions as to when, how often, and how much drug was used or as to the past, present, or future effect of the drug on the performance, health or safety of the worker".

False Positive

It is possible for a legal substance to interact with a substance in a urine specimen resulting in a positive drug test (referred to as a "false positive") even though an illicit drug was not in fact used. Such reactions have reportedly, although infrequently, occurred from antihistamines, ibuprofen and other anti-inflammatory drugs, and poppy seeds. It is also the case that a positive screen can result from the use of prescription medications. Appropriate confirmation procedures should guard against false positive results. Visher and McFadden (1991) found an average false positive rate (across opiates, cocaine, marijuana, phencyclidine PCP, and amphetamines) of 1 to 2 per cent. False positive screens for cocaine are rare due to the uniqueness of the cocaine metabolite molecule detected by the test (Stephens and Feucht 1993). As a result, a confirmation test is not conducted for cocaine. Whereas the confirmatory test for a positive amphetamine screen will enable a more accurate determination of whether the positive result is for the illegal substance, methylamphetamine. Australian research has shown that methylamphetamine isomers cannot be produced by using legally available amphetamines (for example, dexamphetamine) or any other legally available drug (Shearer et al. 1999). However, the urine test cannot distinguish between licit or illicit use of pharmaceutical amphetamine.

A positive test raises many questions that the test alone cannot answer. A positive result, in a sense, is the beginning of the story rather than the end.

[10] However, Hawks and Chiang (1986, p. 86) suggest that the cutoffs are high enough to make such a possibility highly improbable.

Manno (1986, p. 55) suggests that some of the questions that it raises include:

- Is the person using the drug chronically?
- Are they using the drug intermittently?
- Are they addicted to the drug?
- Were they taking the drug under prescription?
- Were they under the influence of the drug at the time the urine was collected?

The only method available to answer many of the questions is to ask the individual concerned. In the DUMA project, detainees are also asked a series of self-report questions on their drug use and criminal behaviour.

What Does a Negative Test Result Indicate?

In the vast majority of cases, a negative test result indicates that there is no presence of the drug or its metabolites in the urine at that time. However, it does not mean that the person has never used the substance at some point just before being arrested. In particular, cocaine has a short half-life and even its metabolites may only be present in the urine for 24–36 hours after use (see Table 4). A number of factors can affect the amount of drug present in the urine at the time the sample was taken. These include the characteristics of the drug, the amount ingested, and the form in which it is ingested physical and pharmacological characteristics of the user; and pathological factors such as genetic disorders, body water, and menstruation (Bigger 1979, p. 30, Chiang and Hawks 1986). It is possible that the person uses drugs intermittently or has recently ceased their use.

False Negative

A negative result does not guarantee that the individual did not consume the drugs prior to being tested. As DUMA uses AS4308–1995 cutoffs, it is possible for a specified amount of the drug(s) to be present and still be reported as "negative". The level of the drug may not have been high enough to exceed the test's cutoff level. When this happens, it is referred to as a "false negative". However, most drugs can usually be detected in urine for up to 2 days after being taken; some up to 4 weeks (see Table 4). The DUMA results are, therefore, a conservative estimate of the extent of illegal drugs used at the time of arrest.

Ethical Questions

In much of the literature on drug testing, ethical issues are a recurring theme, depending on the setting in which the drug testing takes place. Although widespread in the United States, routine drug testing in the general workplace is relatively rare in Australia. Major shifts in broad drug policy tend to be led by the Federal Government in Australia. One obvious example was the banning of smoking within federal buildings which has subsequently lead to widespread bans on smoking in the workplace, shopping malls, airports, and eating places. Where the Federal Government has instituted strong drug testing control, it is done in regard to sports policy and the establishment of sports drug testing programs (Buti and Fridman 1999).

Unlike the United States, the Australian Federal Government has not instituted compulsory drug testing as a requirement of employment, although drug testing within the armed services is becoming increasingly widespread. The Privacy Committee of New South Wales (1992, p. 34) recommended in 1992 that "workplace drug testing should be prohibited by legislation other than when:

i. a person's impairment by drugs would pose a substantial and demonstrable safety risk to that person or to other people;

ii. there is reasonable cause to believe that the person to be tested may be impaired by drugs; and

iii. the form of drug testing to be used is capable of identifying the presence of a drug at concentrations above accepted cut-off levels which may be capable of causing impairment."

Routine drug testing, even in the United States, is a recent phenomenon (Mieczkowksi and Lersch 1997). Although the capacity to detect psychoactive drugs has existed since the 1960s, the great advances in the technology really occurred in the 1960s and 1970s. Mieczkowksi and Lersch (1997, p. 11) report that by the end of the 1980s in the United States "drug

monitoring via testing with the criminal justice system had gained considerable momentum. With the development of rapid, cost-effective drug testing the idea of a criminal justice-based drug monitoring system became more realizable". In addition, "aggressive" testing was promoted via drug testing in the workplace.

Bigger (1979) advises that urinalysis testing has been criticised for usually one of three reasons:

a) it is "dehumanising";

b) it is an infringement on civil rights; and

c) it is at odds within a treatment regime which is primarily based upon trust rather than "doubt and suspicion".

Bigger argues that, within the treatment setting, urinalysis can be counterproductive, but this is dependent on the way in which the information is used rather than on the tool of urinalysis. In the United States criminal justice setting, urinalysis results can be used for punitive purposes such as the withdrawal of privileges within the prison environment, or revocation of parole or bail.

Crowe (1998, p. 1) argues that "drug testing can be used as an intervention tool to help youth overcome denial of substance abuse problems, hold them accountable for their behaviour, and underscore a consistent message to all youth about striving to live drug free". In particular, drug testing of youth in the criminal system is seen as a way of identifying early substance abuse and addressing the problem earlier rather than later. At the individual level, test results can:

- help identify recent use of illicit drugs;
- make recommendations for court dispositions;
- help develop treatment plans; and
- make referrals to appropriate treatment agencies.

At the aggregate level, such information helps law enforcement and treatment agencies learn more about substance use in their local community. Crowe (1998, p. 34) suggests that in the United States at least "legal liability … might result from failing to detect and treat illicit drug use".

Detainees in DUMA are asked if they will participate in a federally-funded research study. They are assured of confidentiality; they are told there is a questionnaire to complete, and a urine sample will be requested at the conclusion of the interview. Detainees can choose not to complete the interview, complete the interview but then choose not to provide the urine sample, or to complete both. It is common within illicit drug research in Australia to pay interviewees for their time; DUMA does not pay detainees. However, depending on the location detainees are offered a small snack (such as a confectionary), or a drink such as coffee or tea.

There are a number of important questions that DUMA seeks to answer:

1. Does urinalysis provide more valid results on recent drug use than self-reported drug use?
2. Is the group that agrees to the interview but fails to provide a urine specimen significantly different from those who complete both?
3. Does the provision of a "snack" make any difference to compliance levels?
4. Does the provision of the "snack" prior to or after the completion of the process affect compliance levels?
5. Do the characteristics of the interviewers affect the urine compliance levels?

From a research perspective, these are important questions, as the answers will determine the utility of urine testing within this setting. If the determination is that there is utility, then the methodology for collecting the specimens will have been developed. From a policy perspective, having the best estimates are desirable. It is not always necessary to have these estimates accurate to the second decimal place (unlike pure research), but policy makers need to be in the right ballpark before starting to play in the game. For cash-strapped policy makers, the real question is whether the usefulness of collecting urine data is worth the methodological rigours, and the cost, versus the quality of the data collected. Part of the DUMA project's goal is to assess this.

DUMA Protocols

Urine drug testing is extremely accurate and reliable when all aspects of the testing process are done properly (Council on Scientific Affairs 1987). On the other hand, the information obtained may be very misleading and inaccurate when poor procedures or testing methods are used. Testing for DUMA is being undertaken by Pacific Laboratory Medicine Services (PaLMS), Northern Sydney Area Health Service; Toxicology Unit, Macquarie Hospital Campus, North Ryde, New South Wales. To minimise the impact of differential procedures in laboratories, all the samples are sent to the one laboratory.

In the case of DUMA, the results from urine tests are to be used for research purposes only, therefore, the high standards required in the data collection and drug testing procedures do not necessarily apply. There is a trade-off that occurs in terms of the quality, cost, and research questions. Decisions have to be made in terms of how many and which drugs to test for, and whether to undertake confirmatory testing on positive screens. Based on expert advice and the experience of the United States and United Kingdom ADAM programs, screens are being undertaken for 6 classes of drugs with confirmatory tests on positive screens for opiates, benzodiazepines and amphetamines.[11]

Specimen Collection

Detainees are told at the beginning of the interview that a urine specimen will be asked for on completion of the interview. As the collection is not for legal purposes, it is unlikely that detainees will seek to adulterate or substitute the specimens; they can simply refuse to provide a specimen. However, one or two may do so. To guard against such activity, temperature

[11] In the United States, the program screens for 10 classes of drugs—opiates, amphetamines, cannabis, methadone, cocaine, benzodiazepines, PCP, methaqualone, propoxyphene, barbiturates. Confirmations are only undertaken for positive amphetamine screens.

strips are on each collection bottle and interviewers are required to read the temperature within 4 minutes of urination. The acceptable range is 32.4C–37.5C. Where the temperature range falls outside the range, the arrestee is asked to provide another specimen. They can refuse at this point.

Dilute specimens can be detected by measuring creatinine concentrations. Out of 826 collections to date, the laboratory has reported 11 samples with low creatinine values. It is possible for samples to be "naturally" dilute if fluid has been recently consumed. Of the 11 samples, only 2 had zero creatinine values that the laboratory indicated were definitely not urine samples. Of the remaining 9 samples, 5 samples still had positive screen results (4 for cannabis, 4 for benzodiazepines, and 1 for methadone), indicating multiple substance use in some cases.

Specimens are collected and transported in standard plastic containers with resealable lids. There is always the risk of a collection kit breaking or the container not being sealed correctly. To date, there have been three instances where containers have leaked in transport to the laboratory.

The Laboratory

Identifying the presence of a drug is not as straightforward as many people believe. It requires "analysts that are properly trained and that they possess the interpretative skills required for reliable specimen analysis" (Jenny 1989, p. 16). Analysts need to understand how drugs break down into their constituent parts. For example, heroin rapidly metabolises into MAM within a matter of minutes of being injected and this in turn metabolises into morphine. Morphine is then usually excreted in urine as morphine-3-glucuronide. Similarly, cocaine has a short half-life and it is necessary to analyse for one of its longer-lived metabolites such as benzoylecgonine (BE) (Jenny 1989).

Overseas experiments have provided documented cases of poor laboratory practices and unreliable urine test results. Analysts need to have a thorough understanding of the relative cross-reactivity and detection limit for each specific drug. These requirements and procedures to guard against poor testing are outlined in AS4308–1995 document. In addition, test results can be affected by the use of

- different immunoassay reagents in the testing (Huestis et al. 1995);

- variations in the calibrations of machines across sites; and
- undertaking the screening and confirmatory testing at different places requiring transfer of the specimens.

The laboratory used by DUMA is accredited by the National Association of Testing Authorities (NATA) to perform medico-legal drug analysis according to AS4308–1995. It is important that both the screening and confirmatory tests are undertaken at the one laboratory; PaLMS provides this service. Either the manufacturer or the laboratory has validated immunoassays and the laboratory uses two independent quality controls for each assay. The laboratory treats all urine samples with beta glucuronidase (an enzyme) prior to analysis to enhance the identification of opiate and benzodiazepine drugs. The GC/MS confirmation for opiates includes beta glucuronidase hydrolysis to enhance the detection of morphine.

The laboratory also supplies all urine collection kits with temperature strip, chain of custody request forms, shipping boxes that met IATA regulations for transport, and arranges for the contract couriers to deliver and collect the boxes from the designated sites.

Some Examples from DUMA Data

Figure 2 provides a flow diagram indicating the drug testing process and its likely outcomes in the context of DUMA. The DUMA samples are from people who have not only been detained but have also been brought to the watchhouse for formal charging procedures. These people are usually apprehended for a serious offence, are "known" to police, have a history of prior arrests, or have outstanding warrants; many of them are familiar with the criminal justice system. They are more likely to be involved in a range of deviant activities, including drug use, than citizens who have not had formal contact with the police. An important empirical question is whether those who are detected with illicit drugs in their urine are regular drug users. This question can be answered by using the self-report data—future research will address this issue.

Table 7 provides examples of urine results from 7 individuals. They have been specifically chosen, as they provide examples of the various issues in regard to interpreting urine results. The first person has a positive screen for opiates (cutoff value (CV) =0.30) and the confirmatory test identifies morphine as the metabolite. Case 2 also has a positive screen for opiates, as well as cannabis (CV=50), benzodiazepines (CV=0.10), and methadone (CV=0.30). Confirmatory tests detect MAM, morphine and codeine; MAM is a clear indication of heroin use. The confirmatory test for benzodiazepines indicates the presence of oxazepam. Case 3 has a positive screen for cannabis and opiates. In the latter case, both morphine and codeine is detected with a higher concentration of the former, indicating that probably heroin has been used. It is important to note that small amounts of codeine in specimens from heroin users are the result of codeine being present in heroin as an impurity (Baselt and Cravey 1995). Case 4 also reveals both codeine and morphine with the former having higher concentration values. In this circumstance, codeine has probably been ingested. Case 5 has a positive opiate screen but only codeine is confirmed. Cases 1 to 5 show positive screens for opiates in all cases but the confirmatory tests indicate that attributing this to heroin is somewhat more difficult. We can probably

Figure 2: Drug Testing Process and Likely Outcomes in DUMA

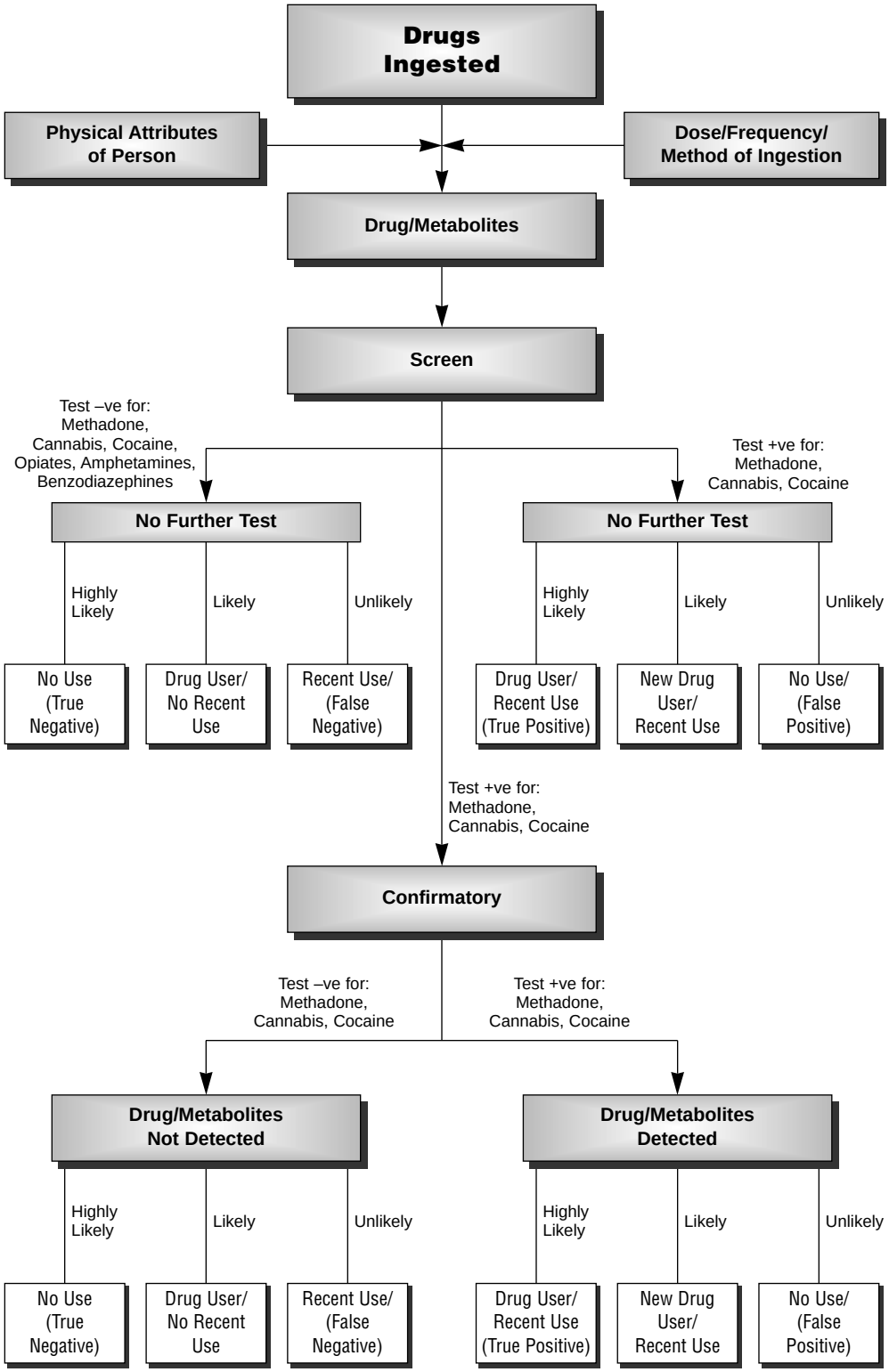


Table 7: Some Examples of Urinalysis Results from DUMA*

Screen results							Confirmation results							
I.D.	Cannabis	Benzodia-zepines	Opiates	Methadone	Cocaine	Ampheta-mines	Drug	Value	Drug	Value	Drug	Value	Drug	Value
1	12	0	**3.61**	0	0	0	Morphine	3150						
2	**56**	**0.17**	**9.45**	**0.34**	0	0	Morphine	36400	Codeine	7420	MAM	2440	Oxazepam	1820
3	**110**	0	**8.87**	0	0	0	Morphine	18100	Codeine	630				
4	1	0	**7.68**	0	0	0	Morphine	1400	Codeine	14200				
5	**98**	0	**1.3**	0	0.01	0.03	Codeine	280						
6	**78**	0	0	0	0	**2.09**	Amphet	5700	Meth amphet	21000				
7	**52**	0	0.01	0	**5.73**	**2.49**	Amphet	26000	Meth amphet	> 50000	MDMA	>50000	Phentermine	12000

*Bold figures indicate positive screen results.

conclude that 3 of the 5 cases have recently used heroin; we cannot conclude this for the other 2 cases.

Case 6 provides an example of positive screen for cannabis and amphetamines. The confirmatory test for the amphetamines indicates both amphetamine and methylamphetamine have been used. The use of the latter indicates definite illegal use of the drug while use of amphetamines may be either legal or illegal. The final example shows a positive screen for cannabis, cocaine, and amphetamines with the confirmatory test, again indicating illegal use of methylamphetamine as well as MDMA.

In general, the positive results for opiates, methadone, cocaine, and amphetamines indicate use in the past 48 hours while a positive result for benzodiazepines indicates use in the past week. For cannabis, a positive result indicates use anywhere from the past day to the past 30 days.

Conclusion

The initial participation rates in DUMA are encouraging. Out of 980 detainees approached in four watchhouses, 814 agreed to voluntarily answer a series of questions about their drug use and criminal activities. Of these, 565 agreed to provide a urine specimen for research purposes only.[12] These responses suggest that with the correct protocols, trained independent interviewers, and police cooperation and support, monitoring of drug use amongst detainees for research purposes is possible.

Urine testing is seen by law enforcement as an important component of the program, as this data provides independent corroboration of drug use activity. However, this paper has indicated that urine testing, like self-report data, has limitations. These limitations need to be openly acknowledged and understood. It is in fact the combination of self-report and urine testing that makes DUMA a potentially powerful law enforcement monitoring tool.

Although hair testing will increase the number of detected long-term drug users, it cannot identify drug use at the time of arrest. Despite the pluses and minuses of each form of technology, Mieczkowksi and Newel (1993, p. 65) concluded from their analysis of the two that "compulsive daily users are highly likely to be identified regardless of the assay medium. Sporadic, or moderate, users are more likely to pass a urine screen and fail a hair screen".

It is important to acknowledge that not only is urine testing not an "exact science" (Harrison 1995, p. 98) but that "even experts will vary in their opinions" (Manno 1986, p. 57). In discussing the rapid advances in drug testing, Mieczkowksi and Lersch (1997) indicate there are currently on the horizon a number of advances that will overtake urine testing. These include hair analysis, sweat patches, smart patches, saliva testing, and ion mobility spectrometers. However, at this time urine testing remains the most cost-effective drug testing technology available in Australia.

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12 These figures vary across publications, as the numbers at any one point in time will represent the most recent available data.

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