



No. 205

Drug Detection and its Role in Law Enforcement

John H. Lewis

The detection of drugs has an important role to play in many areas of society, such as sport, suspicious deaths, violent crime, and travel and work safety. Drug testing technology has been available for the past 40 years, but it is only in the past 10 years that Australia has begun to use drug testing on a much wider scale, particularly within the criminal justice system. This is due to two factors—an increase in drug-related problems in our society and advances in the technology itself.

Currently, testing for illicit drugs is primarily through urinalysis. Less invasive methods are available but have limitations, as this paper reports. Another problem area is the capacity for current drug detection technologies to differentiate between use and intoxication. Although such matters appear arcane and of little relevance to the daily lives of citizens, these are important matters within a law enforcement context where individuals can be deprived of their liberty.

The development and practical application of new drug detection technologies has the potential to play an increasingly important role in law enforcement efforts to track the source of drugs entering Australia. However, it is clear that further technological developments are needed and this requires significant investments in training and research.

The issue of drug testing raises wider questions about the extent to which we should act to detect drugs in the first place. These are difficult questions which require community discussion and debate to inform policy.

Adam Graycar
Director

Historically, the role of drug detection has been in the elucidation of cause of death in suspected poisonings or overdoses (Curry 1963). Since the 1960s drug testing has played an important role in monitoring compliance among patients receiving methadone as opiate substitution therapy. Criminal justice agencies have also looked to drug detection to assist them in their decision-making processes. The best known, and now widely accepted, drug testing regime in the criminal justice arena is random breath testing for alcohol.

As the technology has advanced, and the relative costs have declined, testing for illicit drugs has been introduced into prisons and the courts. Increasingly, drug testing is being used to identify drug-related offenders, to determine if offenders on probation or parole are using illicit drugs, and to assist drug courts in monitoring illicit drug use amongst their clients. Law enforcement agencies are also using drug detection technology to analyse drug seizures to determine their compounds but also to identify their origins in the global drug market. On the other side of the coin, random drug testing of police is becoming more widespread. As a result, the monitoring of drug detection methods and advances in technology in this arena are of critical importance to policy-makers.

History of Drug Detection

The advent of organic chemistry in the early nineteenth century allowed chemists to isolate pharmacologically active substances from plant material and to synthesise a number of drugs. The approximate dates

AUSTRALIAN INSTITUTE
OF CRIMINOLOGY

trends

&

issues

in crime and criminal justice

May 2001

ISSN 0817-8542

ISBN 0 642 24230 5



Australian Institute
of Criminology
GPO Box 2944
Canberra ACT 2601
Australia

Tel: 02 6260 9221

Fax: 02 6260 9201

For a complete list and the full text of the papers in the Trends and Issues in Crime and Criminal Justice series, visit the AIC web site at:

<http://www.aic.gov.au>

when many of today's commonly abused drugs were first isolated or synthesised are shown in Table 1. The capacity to chemically identify the use of particular drugs has been available for more than 100 years for many of the common substances such as cocaine, heroin and amphetamines. However, the capacity to engage in mass detection was limited by a range of factors including:

- techniques that were inefficient and non-specific;
- lack of experienced toxicologists; and
- poor laboratory performance (Normand, Lempert & Brien 1994, p. 179).

Drug analysis was introduced in the United States in the mid-1960s as a means of monitoring patients who were undergoing methadone substitution therapy for heroin dependence (Dole, Kim & Eglitis 1966). The analytical technique that was developed was called thin layer chromatography (TLC). TLC consisted of applying a concentrated organic extract of urine onto a silica-coated glass plate that was then dipped into a glass tank containing buffered solvents. Effectively, the drugs are separated from the biological matrix by means of their relative affinity towards the solvent or silica. The plate is then sprayed with a series of chemicals and the drugs are identified based on the colours that appear on the plate. TLC is still in use for clinical applications, however it is not recommended for medico-legal applications due to its lack of sensitivity and subjectivity in interpretation.

Drug detection in law enforcement began in earnest during the latter days of the Vietnam War, when it became apparent that many United States servicemen were dependent on heroin. The first mass screening technology for opiates, the free radical assay technique (FRAT), was introduced in 1971 by the Syva Corporation of Palo Alto, California (Leute, Ullman & Goldstein 1972). FRAT was quickly superceded by the enzyme-multiplied immunoassay technique, EMIT (Schneider et al. 1973), the forerunner of most of today's drug screening techniques.

Today, immunoassay screening procedures are used almost universally for both clinical and medico-legal drugs of abuse testing. They are ideally deployed in automated high-throughput biochemical analysers. The advantages of immunoassay screenings are that they:

- have a rapid turnaround time;
- use a very small volume of sample (10ul);
- are automated;
- are sensitive;
- have a low cost per test; and
- are selective—there are individual assay kits for different drug groups.

The disadvantages of immunoassay techniques are that they:

- can produce false positives and negatives;
- are not available for many drug groups; and
- are subject to false results due to adulteration;

Manufacturers of immunoassay kits attempt a compromise between sensitivity and specificity. Sensitivity measures the extent to which the test correctly identifies those who have been using; specificity refers to the ability of the test to accurately identify non-drug users. A good screening test should have both high sensitivity and specificity. Most immunoassays cannot distinguish between structurally related substances of the same drug group (for example, codeine and morphine, or amphetamine and methylamphetamine). Thus, screening tests have high sensitivity but can have poor specificity. As many of these drugs are legally prescribed, it becomes imperative that absolute identification is performed using a more definitive analytical technique such as gas chromatography-mass spectrometry (GC/MS).

In order for any drug test result to be defensible in a court of law, absolute identification must be made using a chromatographic technique coupled to mass spectrometry. GC/MS is the technique of choice used to identify drugs and metabolites in a specimen. Essentially, the specimen is passed into the mass spectrometer where it is ionised and broken down into unique fragments. These

Table 1: Dates when many of today's commonly abused drugs were first synthesised

Drug type	Year first synthesised
Morphine	1810
Codeine	1832
Cocaine	1850
Barbituric acid	1864
Heroin	1874
Amphetamine	1887
Aspirin	1899
Barbitone	1903
MDA*	1910
MDMA**	1914
LSD	1938

* Methylendioxyamphetamine

** Methylendioxymethylamphetamine (Ecstasy)

fragmentation patterns of individual drugs are matched against reference spectra in the computer's database, allowing for the identification of the compounds. Unfortunately, confirmatory tests are considerably more expensive than the initial screening test.

Working to Recognised Standards

In medico-legal situations, use of the aforementioned techniques without a minimum set of guidelines may invalidate the results. There were a number of critical reports on drug testing laboratories in the United States during the 1980s. In July 1987 the United States Congress required urine testing for all federal employees and that the testing met technical and scientific guidelines and standards of practice (Normand, Lempert & O'Brien 1994, p. 179). In 1988 the United States introduced its mandatory guidelines for legally defensible drugs of abuse testing (United States Department of Health and Human Services 1993). Three months later the National Institute for Drug Abuse implemented a National Laboratory Certification Program. Australia was the first country to produce a national standard for medico-legal drug testing in 1995 (Standards Australia 1995). A revised standard was released in 2001 (Standards Australia 2001). The United Kingdom and European Union are currently developing their own standards. The purpose of such guidelines is to ensure that

laboratories undertaking drug analysis use proper calibration and controls in the analysis, and adhere to a minimum set of criteria for acceptance of a result. In essence, those responsible for laboratory reports must be accountable in a court of law.

New Advances in Urinalysis Screening Tests

As the pressure for cheaper, more accurate and easier screening methods has increased, immunoassay techniques are becoming more sophisticated and specific. A new assay for 6-acetylmorphine (6-AM) has recently been released by the Microgenics Corporation in the United States. Unlike other enzyme immunoassays that show significant cross-reactivity to morphine, codeine and pholcodine, the 6-AM test is specific to the unique metabolite of heroin and is thus unequivocal proof of heroin use. Similarly, Microgenics Corporation has developed a specific assay for the major metabolite of methadone—2-ethyl-1-5, dimethyl-3,3,-diphenylpyrrolidine (EDDP). The advantage of this assay is that in detecting the major metabolite rather than parent methadone, there exists a far greater opportunity for identifying methadone use than by using traditional techniques calibrated on methadone. This is especially important, as excretion of methadone, unlike EDDP, is pH dependent, and is thus highly variable.

As new drugs emerge onto the market, new reagents are being developed to more accurately identify those drugs. For example, drug testing can now identify crack cocaine, as opposed to just cocaine (Jacob et al. 1990).

Until recently, urine has been the matrix of choice for identifying illicit drug use. The main advantages are that:

- most drugs or metabolites are excreted into urine in relatively high concentrations;
- sample collection is not physically invasive;
- analytical procedures are well established and require minimal sample preparation;

- screening procedures can be automated; and
- detection of drugs or metabolites is indicative of recent ingestion;

Some disadvantages of urine are that:

- collection procedures require strict supervision while allowing for individual privacy;
- samples are amenable to adulteration, substitution or dilution (Cody 1990); and
- drug test results cannot identify time, dose or pharmacological effect of ingestion.

Alternative Biological Specimens

In various medico-legal situations alternative biological specimens to urine are being used. Many drugs are excreted into sweat, saliva and hair and these specimens can provide forensic chemists with useful information on drug use. Their relative windows of detection determine individual suitability for drug detection in law enforcement. As mentioned previously, a criticism of urine as a suitable biological specimen is that drugs can only be detected for one to five days after use. Consecutive samples taken within that time frame may not necessarily identify repeated drug use. Conversely, for many situations it may be appropriate to look at patterns of drug usage over periods of weeks or months. For example, persons previously brought before the courts on drug-related offences are often required to undergo urine testing for a conditional period. Thereafter, while on probation, it may be more appropriate and cost-effective for these people to wear a sweat patch. The device is designed to be worn on the body, usually the upper arm or torso, for periods of one to four weeks. Drugs excreted via sweat are absorbed onto a pad within the patch. The device is sent to a laboratory for analysis. Drugs that have been identified in sweat include ethanol, amphetamine, methylamphetamine, cocaine and its metabolites, heroin, 6-AM, morphine, codeine and methadone.

The advantages of sweat as a matrix are that:

- the subject is not required to present for regular urine tests;

- it is a cumulative measure of drug use;
- it is non-invasive and simple to collect;
- the parent drug is present; and
- it can measure a range of drugs within a defined period.

The disadvantages of sweat are that:

- there is high individual variability in sweating;
- there is a possibility of contamination;
- it requires highly sensitive instrumentation; and
- very few laboratories are capable of analysing the matrix.

Saliva

For very different reasons there has been significant interest by both the scientific and lay communities towards saliva testing. Saliva is a colourless liquid secreted into the oral cavity by a number of salivary glands. These are made up of major glands (parotid, submandibular and sublingual) and minor glands (labial, buccal, palatine and lingual) (Inoue, Seta & Goldberger 1992). Researchers in the 1960s first identified a number of therapeutic drugs excreted into saliva (Borzelleca & Cherrick 1965; Borzelleca & Doyle 1966). Idowu and Caddy (1982) reviewed a number of forensic applications of drug identification in saliva. Peel, Perrigo and Mikhael (1984) described the use of saliva as a means of identifying drug use in impaired drivers.

Gross et al. (1985) analysed saliva samples from male and female cannabis users. They found mean measured tetrahydrocannabinol (THC) levels at 0.5 hours after smoking were 329 ng/mL in male chronic users and 154 ng/mL in occasional smokers. The respective mean concentrations dropped gradually to 6 ng/mL and were not detectable five hours after smoking. Maseda et al. (1986) measured THC in the saliva of beer drinking and non-drinking subjects. They found that in non-drinking subjects, the concentration range of THC in saliva one and four hours after smoking was 50–96 ng/mL. In subjects who drank beer after smoking, saliva levels of THC were 34–74 ng/mL. The authors

suggested that drinking removed the drug from the oral cavity.

In Australia there has been much interest in the potential use of saliva analysis for the determination of recent cannabis use. In certain industries, particularly mining, the possibility of impairment due to cannabis has become the focus for drug testing of employees. Many unions have actively resisted the implementation of random workplace urine testing, claiming recreational use of marijuana would result in a positive test some days after use, long after any possible impairment, and thus affecting employment prospects. As the window of detection for cannabis in saliva is very short compared to urine, employees have thus opted for saliva testing over urine testing.

Persons suspected of drug-related driving offences who have returned a measurable level of THC in their blood are often charged with driving under the influence of marijuana. Roadside saliva testing with appropriate legislation may be useful in identifying impaired drivers. There are, however, three major problems with saliva testing. First, existing devices for measuring THC in saliva lack the necessary sensitivity to be of any practical value (European Union 2000). Second, very few laboratories have the expertise or adequately sensitive instrumentation to perform saliva testing to medico-legal standards. New draft United States mandatory guidelines for drug testing (National Clearinghouse for Alcohol and Drug Information 2000) impose a saliva THC cut-off of 4 ug/L. Finally, as described earlier, THC saliva levels drop rapidly to almost undetectable levels within a few hours after smoking. THC is not actually secreted into saliva (Thompson & Cone 1987; Hawkes & Chang 1986) but is detected as debris within the oral cavity. Thus, there will be much variability in detecting THC in oral fluid. Any suggestion of impairment due to cannabis is predicated on residual matter not being removed by drinking fluids or mouthwashing soon after smoking.

Hair

The use of hair as a matrix for identifying drugs was reported by Harrison, Gray and Solomon (1974). Using radioimmunoassay, Baumgartner et al. (1979) identified heroin and its metabolites in hair samples taken from drug users. In the last 10 years a great deal of interest has been shown in the use of hair as an alternative biological matrix for the medico-legal detection of illicit drug use.

Hair consists principally of a shaft (projecting from the surface of the scalp) and a follicle (the part beneath the scalp surface). The follicle comprises a root, hair matrix and blood capillaries. Drugs are incorporated into hair strands via a number of pathways. First, ingested drugs appear in the blood and are carried via capillaries in the scalp into the hair root and finally up into the shaft. Second, drugs excreted into sweat and sebaceous glands in the scalp are absorbed into the hair. Finally, drugs can be incorporated into the hair shaft by external sources such as sweat, other aqueous media or external contamination (Inoue, Seta & Goldberger 1995).

The use of hair as evidence of use or lack of use of drugs has already been tested in United States courts (Huestis 1996). Hair analysis provides a unique advantage over other matrices, such as blood or urine, due to the fact that many drugs are incorporated into the hair shaft through ingestion and remain in the hair at all times. Thus, hair has the widest window of detection of all biological matrices—ranging from days to years. In general, drugs can only be removed by cutting the hair, although repeated washing or treating hair may diminish drug concentrations. Unlike urine, it is not possible to dilute or otherwise adulterate hair in order to evade a drug test. Unfortunately, before hair can be truly accepted by a court of law as primary evidence of drug use, a number of complex issues need to be resolved.

For qualitative analysis, hair provides a useful matrix for demonstrating exposure to drugs over a loosely defined time span. A number of researchers have

measured drug levels in segments of hair strands, using the average hair growth of one centimetre per month in order to calculate an approximate date of drug exposure (Valente et al. 1981). Unfortunately, the value of segmented hair analysis is limited by a number of variable factors. Although mean hair growth is one centimetre per month (Montagna & Van Scott 1958), there is significant variation (as little as 0.7 centimetres and as much as 3.6 centimetres). Furthermore, there is variability in hair growth from different areas of the body and scalp. The posterior vertex is now the acknowledged preferred site for hair sampling.

The value of both qualitative and quantitative hair analyses is further diminished because of differences in ethnicity and hair colour in the uptake of certain drugs. These issues are particularly relevant in law enforcement, where racial bias could conceivably affect the processes of natural justice. Cone and Joseph (1996) reported that there was mounting evidence to suggest the existence of bias in hair testing for drugs because of their binding to melanin, the pigment responsible for hair colour. Cocaine in particular was detected in significantly higher concentrations in female African-Americans than in Caucasians, the former having a higher melanin content. Kelly et al. (2000) studied the relationship between amphetamine uptake and different hair colour. The authors found the highest uptake in medium-brown hair and a very low uptake in black hair.

It is unlikely that any comparable studies have been conducted in Australia. However, should hair testing become part of any law enforcement procedure, Indigenous Australians and ethnic minorities could be disadvantaged relative to fair-haired Caucasians unless proper controls for bias are put in place. There are other unresolved issues that may preclude the use of hair testing as a preferred protocol in law enforcement. These include problems of contamination, lack of agreement on analytical methodology and a paucity of standard guidelines.

Testing the Drugs Themselves

Forensic laboratories assist law enforcement through the analysis of drugs seized by police. There are primarily two reasons for doing so. It is often difficult for police to determine exactly what has been seized. Analysis of the substances can tell police what compounds, including adulterants, have been used to produce the drug. Further, it is possible to determine the overall level of purity. Analysis of drug seizures in Australia has shown enormous variation in the purity of drugs seized by police (see ABCI 2001). Analysis of purity levels enables law enforcement to make judgments about:

- the need for health warnings to unsuspecting consumers;
- which level of the drug market the arrestee might be at; and
- the links between markets.

Drugs can be analysed to determine their origins. This information can aid national and international agencies in monitoring and targeting foreign drug distribution networks (DEA 2000; AFP 2001). This is particularly important for those agencies responsible for manning borders and deterring importation of illicit drugs. Such intelligence can enable them to allocate their scarce resources with greater accuracy. The United States Drug Enforcement Agency (DEA) has developed heroin, cocaine and methamphetamine signature programs. Similar developments are occurring in Australia with the Australian Federal Police's National Heroin Signature Program (NHSP) (ABCI 1999; AFP 2001). The increasing role of forensic science and the need for state-of-the-art laboratories has resulted in the DEA upgrading and expanding its laboratory facilities throughout the late 1990s. In addition, they are developing satellite and mobile laboratories to provide on-the-spot analysis of seized drugs (DEA 2000). The availability of NHSP data should enable Australian law enforcers to:

- target overseas countries that are exporters of illicit drugs to Australia;

- track distribution networks both externally and internally within Australia; and
- evaluate the effectiveness of drug law enforcement through monitoring the proportions of drug seizures by country of source (ABCI 1999; AFP 2001).

Drug Testing and Policy Questions

Even with the most accurate and precise analytical techniques, there are many policy questions to which drug test results cannot provide clear answers. Unfortunately, science has not yet advanced to the same level as the blood-alcohol concentration model. A positive result from drug testing procedures for illicit drugs simply means that the person has been exposed to the identified drug. The test result cannot establish cause and effect relationships; these are inferences that need to be supplemented with a range of data from other sources. Many issues concerning level of impairment, time of use, route of consumption, dose level and chronic use cannot be determined from the drug test results alone (Normand, Lempert & O'Brien 1994). With appropriate research support, technological advances will overcome some of these issues. A key priority for policy-makers is the development of a testing technology and standards that will enable police reliably to detect intoxicated illicit drug use by motorists.

Similarly, identification of the source countries of illicit drugs is an important aid to law enforcement, but it does not on its own address other important issues such as the form and structure of a particular drug organisation, how that organisation's networks are developed and maintained, the methods used in transporting the drugs and the quantity being transported. However, drug testing can be a powerful tool when used with other information; forensic science cannot solve crime alone but it can be an important and sometimes critical weapon for law enforcement.

In the arena of monitoring and evaluation for policy-making

Table 2: *Of those testing positive to the drug, the percentage who also self-reported recent use*

Drug class	Self-reported use	
	Last three days	(n)
Amphetamines	61.6	(99)
Cannabis	87.0*	(509)
Opiates	66.9	(178)

* Self-reported use is for 30 days
Source: Australian Institute of Criminology, DUMA Collection [computer file]

purposes, researchers are now using drug testing to supplement self-report data (Harrison & Hughes 1997). The Australian Institute of Criminology currently has a pilot study examining drug use amongst people detained by police. As part of this study, detainees are asked to participate in a confidential and voluntary interview and to provide a urine specimen (Makkai 2000a, 2000b). Comparing self-reported use with urine results indicated that:

- 61.6 per cent of those who tested positive to amphetamines admitted use in the past three days;
- 66.9 per cent of those who tested positive to opiates admitted use in the past three days; and
- 87 per cent of those who tested positive to cannabis admitted use in the past 30 days (see Table 2).

The policy implications are clear:

- relying on self-report data alone for monitoring of illicit drugs in the criminal justice system may underestimate recent use;
- relying on self-report data that police collect for standard reporting systems may underestimate recent use; and
- the use of drug detection technology can improve our knowledge by allowing us to more rigorously test interventions and research the relationship between drugs and crime.

Drug Testing and Law Enforcement

The use of drug testing in law enforcement has many critics. Conversely, in both clinical and forensic cases, the role of drug testing has been demonstrated to be of critical importance in the identification of a cause of poisoning or death. Yet whenever the same technology and protocols

are used to provide evidence leading towards punishment, conviction or exposé of (mainly illicit) drug use, questions are invariably raised about the reliability of testing, invasion of privacy or lack of correlation between drug use and impairment. There is no single accepted procedure for deterring drug traffickers, maintaining drug-free jails, reducing drug-related fatalities in drivers, or impacting on drug-associated crime. Drug testing seeks to provide corroborative evidence to courts and to law enforcement officers in their line of duty. While technology has become more sophisticated and correspondingly less expensive in the last 10 years, there still remains an overall question of cost-benefit for drug testing to be fully accepted by many organisations and the community at large. Much of the technology described has been well documented and validated. Drug testing has already been implemented in jails, drink-driving legislation and in drug courts. Its value to law enforcement and the community may only be recognised by careful analysis of data produced by well designed pilot projects. In order for drug testing to become a more integral part of law enforcement, policy-makers and law enforcement officers must educate the general public and politicians of the benefits of using new technology to improve the practice of policing and criminal justice. Furthermore, the use of new technology can improve our evidence basis by providing more rigorous scientific methods for monitoring and evaluation of criminal justice practice. However, this will not happen without appropriate levels of investment in technology and research.

References

- Australian Bureau of Criminal Intelligence (ABCI) 1999, *Australian Illicit Drug Report 1997-98*, Australian Bureau of Criminal Intelligence, Canberra.
- 2001, *Australian Illicit Drug Report 1999-2000*, Australian Bureau of Criminal Intelligence, Canberra.
- Australian Federal Police (AFP) 2001, *National Illicit Drug Strategy: Initiatives, November 1997-December 2000*, Australian Federal Police, Canberra.
- Baumgartner, A.M., Jones, P.F., Baumgartner, W.A. & Black, C.T. 1979, "Radioimmunoassay of hair for determining opiate-abuse histories", *Journal of Nuclear Medicine*, vol. 20, no. 7, pp. 748-52.
- Borzelleca, J. & Cherrick, H. 1965, "The excretion of drugs in saliva: Antibiotics", *Journal of Oral Therapeutics and Pharmacology*, vol. 2, no. 7, pp. 180-7.
- Borzelleca, J. & Doyle, C. 1966, "Excretion of drugs in saliva: Salicylate, barbiturate, sulphanimide", *Journal of Oral Therapeutics and Pharmacology*, vol. 3, no. 2, pp. 104-11.
- Cody, J.T. 1990, "Specimen adulteration in drug urinalysis", *Forensic Science Review*, vol. 2, pp. 63-75.
- Cone, E.J. & Joseph, R.E. 1996, "The potential for bias in hair testing for drugs of abuse", in P. Kintz (ed.), *Drug Testing in Hair*, CRC Press, Boca Raton, pp. 69-93.
- Curry, A.S. 1963, *Poison Detection in Human Organs*, Charles C. Thomas, Springfield.
- Dole, V.P., Kim, W.K. & Eglitis, I. 1966, "Detection of narcotic drugs, tranquilizers, amphetamines, and barbiturates in urine", *Journal of the American Medical Association*, vol. 198, no. 4, pp. 349-52.
- Drug Enforcement Agency (DEA) 2000, "Forensic sciences", Drug Enforcement Administration, United States Department of Justice, see <http://www.usdoj.gov/dea/programs/forensic.htm>.
- European Union 2000, *Work Package 2: Inventory of State-of-the-Art Roadside Testing Equipment*, Roadside Testing Assessment (ROSITA) Study, see <http://www.rosita.org>.
- Gross, S.J., Worthy, T.E., Nerder, L., Zimmermann, E.G., Soares, J.R. & Lomax, P. 1985, "Detection of recent cannabis use by saliva delta 9-THC radioimmunoassay", *Journal of Analytical Toxicology*, vol. 9, no. 1, pp. 1-5.
- Harrison, W.H., Gray, R.M. & Solomon, L.M. 1974, "Incorporation of D-amphetamine into pigmented guinea-pig hair", *British Journal of Dermatology*, vol. 91, no. 4, pp. 415-8.
- Harrison, L. & Hughes, A. 1997, *The Validity of Self-Reported Drug Use: Improving the Accuracy of Survey Estimates*, National Institute on Drug Abuse, Research Monograph 167, United States Department of Health and Human Services, Rockville.
- Hawkes, R. & Chang, C.N. (eds.) 1986, *Urine Testing for Drugs of Abuse*, National Institute on Drug Abuse, Research Monograph 73, United States Department of Health and Human Services, Rockville.
- Huestis, M. 1996, "Technical and legal aspects of drugs of abuse testing in hair", in P. Kintz (ed.), *Drug Testing in Hair*, CRC Press, Boca Raton, pp. 5-15.
- Idowu, O.R. & Caddy, B. 1982, "A review of the use of saliva in the forensic detection of drugs and other chemicals", *Journal of the Forensic Science Society*, vol. 22, no. 2, pp. 123-35.
- Inoue, T., Seta, S., & Goldberger, B. 1992, "Analysis of drugs in unconventional samples", *Forensic Science Review*, vol. 4, pp. 89-107.
- 1995, "Analysis of drugs in unconventional samples" in R. Liu & B. Goldberger (eds.), *Handbook of Workplace Drug Testing*, AACC Press, Washington DC, pp. 131-58.
- Jacob, P., Lewis, E.R., Elias-Baker, B. & Jones, R. 1990, "A pyrolysis product, anhydroecgonine methy ester (methylecgonidine), is in the urine of cocaine smokers", *Journal of Analytical Toxicology*, vol. 14, no. 6, pp. 353-7.
- Kelly, R.C., Mieczkowski, T., Sweeney, S.A. & Bourland, J.A. 2000, "Hair analysis for drugs of abuse: Hair color and race differentials or systematic differences in drug preferences?", *Forensic Science International*, vol. 107, pp. 63-86.
- Leute, R.K., Ullman, E.F. & Goldstein, A. 1972, "Special immunoassay of opiate narcotics in urine and saliva", *Journal of the American Medical Association*, vol. 211, no. 11, pp. 1231-4.
- Makkai, T. 2000a, *Drug Use Monitoring in Australia: Drug Detection Testing*, Research and Public Policy Series, no. 25, Australian Institute of Criminology, Canberra.
- 2000b, *Drug Use Monitoring in Australia: 1999 Annual Report on Drug Use Among Adult Detainees*, Research and Public Policy Series, no. 26, Australian Institute of Criminology, Canberra.
- Maseda, C., Hama, K., Fukui, Y., Matsubara, K., Takahashi, S. & Akane, A. 1986, "Detection of delta-9-THC in saliva by capillary GC/ECD after marijuana smoking", *Forensic Science International*, vol. 32, no. 4, pp. 259-66.
- Montagna, W. & Van Scott, E.J. 1958, "The anatomy of the hair follicle", in W. Montagna & R.A. Ellis (eds.), *The Biology of Hair Growth*, Academic Press, New York.
- National Clearinghouse for Alcohol and Drug Information 2000, *Draft Mandatory Guidelines for Federal Workplace Drug Testing Programs*, Substance Abuse and Mental Health Services Administration, United States Department of Health and Human Services, see <http://www.health.org:80/workplace/fedagencies/testing.htm>.
- Normand, J., Lempert, R.O. & O'Brien, C.P. 1994, *Under the Influence? Drugs and the American Workforce*, National Academy Press, Washington DC.
- Peel, H.W., Perrigo, B.J. & Mikhael, N.Z. 1984, "Detection of drugs in saliva of impaired drivers", *Journal of Forensic Sciences*, vol. 29, no. 1, pp. 185-9.
- Schneider, R.S., Lindquist, P., Wong, E.T., Rubenstein, K.E. & Ullman, E.F. 1973, "Homogeneous enzyme immunoassay for opiates in urine", *Clinical Chemistry*, vol. 19, no. 8, pp. 821-5.
- Standards Australia 1995, *AS 4308 Recommended Practice for the Collection, Detection and Quantitation of Drugs of Abuse in Urine*, Standards Australia, Sydney.
- 2001, *AS/NZS 4308:2001 Procedures for the Collection, Detection and Quantitation of Drugs of Abuse in Urine*, Standards Australia, Sydney.
- Thompson, L.K. & Cone, E.J. 1987, "Determination of delta-9-tetrahydrocannabinol in human blood and saliva by high performance liquid chromatography with amperometric detection", *Journal of Chromatography*, vol. 421, no. 1, pp. 91-7.
- United States Department of Health and Human Services 1993, "Mandatory guidelines for federal workplace drug testing programs", *Federal Register*, 25 January (58FR 6062).
- Valente, D., Cassini, M., Pigliapochi, M. & Vansetti, G. 1981, "Hair as the sample in assessing morphine and cocaine addiction", *Clinical Chemistry*, vol. 27, no. 11, pp. 1952-3.

Dr John Lewis is Principal Scientist and Department Head of the Toxicology Unit, Pacific Laboratory Medicine Services, Northern Sydney Health



General Editor, Trends and Issues in Crime and Criminal Justice series:
Dr Adam Graycar, Director
Australian Institute of Criminology
GPO Box 2944
Canberra ACT 2601 Australia

Note: Trends and Issues in Crime and Criminal Justice are refereed papers.