Illicit drug profiling: The Australian experience

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Illicit drug profiling provides law enforcement agencies with physical and chemical information that may assist in identifying and disrupting drug trafficking organizations. Detailed chemical analysis provides information which when compared to historical data allows investigators to determine the geo-location of cultivated drugs such as cocaine and heroin. Similar analyses of synthetic drugs afford information on synthetic route and precursor chemicals. When combined with physical evidence this information may also be used to help establish links between different seizures of illicit drugs. The Australian Illicit Drug Intelligence Program, which is a collaboration between the Australian Federal Police and the Australian National Measurement Institute, was established to acquire chemical and profiling data on illicit drugs and disseminate information to appropriate national and international governmental agencies.

**Keywords:** Illicit drugs; profiling; heroin; cocaine; amphetamine type stimulants

Drug profiling is like any other form of profiling. In essence it is an intelligence-gathering exercise. We profile people, religious attitudes, politicians, art, food and wine. The reason we do this is to learn as much as possible about the subject being ‘profiled’ and use that information for our benefit. Whether this information is useful or not depends entirely on how it is used. In the case of drug profiling we accumulate as much chemical and physical information about the drug in order to assist law enforcement agencies. This may mean intelligence that will help to identify drug trafficking organizations and eliminate or disrupt their activities.

The concept of profiling drugs is not new. Most western nations have at least one forensic institution with the capability to examine illicit drugs in great detail. In particular, the United States Drug Enforcement Administration (US DEA), the German Bundeskriminalamt (BKA) and the Netherlands National Forensic Institute (NFI) have been engaged in profiling illicit drugs for several decades and are expert in the field.

If you observe a drug-related criminal prosecution in Australia the expert witness, if he or she is called at all, will usually be required to only give evidence as to the identity of the
drug and its purity. The analytical chemistry required is straightforward and quite routine. Determining whether an unknown white powder is heroin, cocaine or not an illicit substance is not difficult and this type of analysis provides little useful information other than what is needed to assist the jury in determining guilt or innocence and the judge in determining an appropriate sentence.

Drugs, however, can tell us so much more about themselves. When you look beyond the identity of the drug itself, say cocaine, there are hundreds of other molecules, many of which can tell a story about the cocaine, e.g. in which country in South America was the coca leaf grown, how and where was the leaf turned into a paste and finally into cocaine hydrochloride for export around the world\(^1\). The same applies to the other cultivated and semi-cultivated drugs such as cannabis and heroin. This is possible because plants such as poppies, *Papaver somniferum*, and coca, *Erythroxylum coca*, acquire characteristics from the soil in which they grow. Other variables, such height above sea level, climate and distance from the coast all affect the plant’s metabolism and hence its internal chemistry. This is reflected in the nature and concentration of certain key marker compounds found upon detailed investigation of the final product. So, coca leaf grown in Colombia and processed into cocaine hydrochloride in Colombia will have a different chemical fingerprint or signature to cocaine obtained from Bolivia.

Synthetic drugs also can tell us much about their history. Unlike legitimate drug production, clandestine facilities in which drugs are manufactured have no quality control and the ‘cooks’ are not usually graduates in organic chemistry. Hence the quality of the product is highly variable. With the exception of some very high-quality production units in the Netherlands most amphetamine, methamphetamine and Ecstasy will exhibit manufacturing by-products revealed by detailed chemical analysis. These by-products can provide much information about the synthetic route and precursor chemicals employed\(^2,3\). The latter provides useful intelligence for government agencies attempting to control industrial chemicals that may be diverted to illicit drug production.

1. **Profiling illicit drugs in Australia**

The Australian entry into drug profiling is a comparatively recent event. The need for this capability in our country has been championed since the early 1990s most strongly by the Australian Federal Police. Following research and development work between 1991 and 1995 the National Heroin Signature Program (NHSP) was established in 1997 as a collaborative project between the Australian Federal Police (AFP) and the Australian Government Analytical Laboratories (AGAL). Funding came from the Federal Governments’ National Illicit Drug Strategy (NIDS).

The NHSP was born of the Prime Minister’s ‘Tough on Drugs’ policy and represented this country’s first attempt at profiling. The focus was on heroin because, at that time, this was the drug creating most concern to the nation’s policy makers in health and drug related crime. Heroine was perceived, and probably correctly, as being one of the most serious threats to the social fabric of Australia’s major cities.

In 2003, with a substantial increase in funding, the NHSP was expanded to become the Australian Illicit Drug Intelligence Program (AIDIP). The new programme aimed at consolidating the work done on heroin and expanding into other major drug types. Again it was a collaboration between the AFP and what had by then become Australia’s National Measurement Institute (NMIA).
Fortuitously the AIDIP came into existence at the same time that the International Drug Profiling Committee (IDPC) was formed. The IDPC comprises representatives from major government forensic institutions in Germany, the United Kingdom, the Netherlands, Switzerland, Sweden, Finland, France, Japan, Hong Kong, the United States and Australia. Attendance at the inaugural and second IDPC meetings helped develop our ideas about just how the AIDIP should begin and progress. Following these meetings each of the authors has spent a considerable time in major laboratories such as the United States Drug Enforcement Administration’s Special Testing and Research Laboratory (STRL). A strong relationship has since developed between scientists from the AFP and NMIA and scientists at the STRL. This has facilitated an excellent exchange of ideas, scientific methodology and operational intelligence.

The AIDIP’s heroin and cocaine signature programmes are based on the equivalent STRL programmes. The signature programmes for the Amphetamine Type Substances (ATS) such as methamphetamine and methylenedioxymethylamphetamine (MDMA or ‘Ecstasy’) are based on programmes developed at the Netherlands’ National Forensic Institute. These ATS signature programmes are also known as ‘harmonized’ programmes because they have been carefully developed by European researchers so that the methodology is transportable and enables easy comparison of results obtained at different European laboratories. Significantly, the STRL has also adopted these ATS programmes.

The AIDIP has two major arms to it: chemical profiling and physical profiling. Chemical profiling involves a detailed chemical analysis of the drugs to provide information that may complement intelligence already acquired by law enforcement. Chemical profiling attempts to provide both strategic and tactical intelligence. Strategic intelligence is information relating to the geographical origin of cultivated or semi-cultivated drugs and the methods of preparation of the fully synthetic drugs. Tactical intelligence is information that can be supplied to law enforcement that may assist in creating or confirming links between drug seizures or criminal groups.

Physical profiling examines other forensic aspects of drug seizures by treating each seizure as a crime scene and adopting a consistent approach across Australia to the examination of each such crime scene. While the chemical profiling is centralized in one laboratory, physical profiling is carried out by teams of physical evidence specialists across Australia. It is therefore important that each team is ‘harmonized’ in their approach to each investigation.

Physical profiling, or ‘Signature 4’, involves many routine techniques used by forensic personnel around the world for all types of crime. For criminal activity, which spans many jurisdictions and associated languages, imaging has proven to be of great importance. Digital images of key features allow the AIDIP to generate reports that can be transmitted through liaison networks around the world including to jurisdictions where chemical drug profiling, or even routine analysis, may still be in development. A set of images depicting an illicit drug concealment can have immediate meaning to not only forensic scientists, but also investigators, community police, customs officers, intelligence analysts and others. This meaning can connect individual seizures or establish an alert for the future. Development in physical profiling is dependent upon establishing which key features should be recorded or measured, whether it be through imaging or scientific measurement. Just as chemical profiling seeks to examine the various constituents of the illicit drug, so too has research been conducted to establish reliable analytical techniques to profile common packaging materials such as plastic bags, films and adhesive tapes. The physical examination of the illicit ‘Ecstasy’ tablet or block of heroin can also reveal connections through minor imperfections in the tool used to press them.
In the end, the two arms of the programme are designed to complement each other. Where there is, for example, an obvious difference in chemical profile, physical aspects such as tablet toolmarks arising from the above imperfections may still establish a link. Similarly, there may be no physical similarities in cases using different methods of concealment, but chemical profiling would still be viable.

2. Heroin

The heroin origin programme endeavours to determine the geographic origin of heroin seizures at the Australian border. The programme is comprised of three chemical fingerprints or ‘signatures’ and the physical ‘Signature 4’.

**Heroin Signature 1—major alkaloids**

The first signature studies the major alkaloids that are present in heroin. In addition to morphine the opium poppy contains other alkaloids such as codeine, thebaine, papaverine and noscapine. These compounds are co-extracted with morphine and are found in varying amounts in heroin. The first signature quantifies the diacetylmorphine, morphine, codeine, acetylmorphine, 6-monoacetylmorphine, 3-monoacetylmorphine, papaverine and noscapine present in the heroin by a capillary electrophoretic technique. Much empirical evidence has been built up over time regarding the levels of these substances in heroin from different regions in the world. By calculating the ratios of these compounds to total morphine and comparing these values with figures obtained on thousands of authentic (known origin) samples it is possible to classify a heroin sample as having been produced in Southwest Asia (Afghanistan), Southeast Asia (Myanmar, Laos, Thailand, etc.), Mexico, or South America (Colombia)4–6.

**Heroin Signature 2—manufacturing by-products**

The chemical reaction that converts morphine to heroin is quite drastic and results in the formation of many manufacturing by-products that are either acidic or neutral in nature. More than 100 such compounds have been identified and characterized by researchers working in profiling laboratories such as the STRL7. These compounds are an adjunct to Signature 1 in identifying the geographical origin of the sample. The AIDIP routinely screens heroin samples for approximately 30 of these compounds using a gas chromatographic–mass spectroscopic technique. Signature 2 offers the possibility in the future of being able to localize the region of origin more precisely.

**Heroin Signature 3—occluded solvents**

During the processing of morphine into heroin a range of solvents are employed. Strangely, solvents used in say Southeast Asia are never used in Southwest Asia. The same applies to the other major heroin producing regions. When heroin is produced traces of the solvents used are trapped in the crystal lattice. By a process known as Static Headspace Gas Chromatography–Mass Spectroscopy8, it is a very simple matter to determine which solvents are present and hence where in the world the processing occurred.

3. Cocaine

Cocaine is an alkaloid found in *Erythroxylum*. There are more than 200 species of *Erythroxylum* but of these only about 17 produce cocaine. Of these 17 species, only 2
produce significant amounts of cocaine: *Erythroxylum coca* and *Erythroxylum novogranatense*. Within each of these two species there are two major variants that produce cocaine. The cocaine origin programme comprises four chemical signatures based on those employed by the US DEA and determines the country of origin in South America and, where possible, the species and variant. Most cocaine seized at the Australian border originates in Colombia, Peru or Bolivia. Again ‘Signature 4’ refers to the physical aspects of the seizure.

**Cocaine Signature 1—major tropane alkaloids**

As with heroin the first area of investigation is the alkaloids present in the coca leaf that are co-extracted with the cocaine. The programme quantifies 14 such alkaloids looking particularly at tropacocaine, 3,4,5-trimethoxycocaine and the cinnamoylcocaines. These molecules are very useful diagnostic markers for origin. They are easily determined by a simple gas chromatographic–mass spectroscopic technique.

**Cocaine Signature 2—the truxillines**

The truxillines are a group of unusual alkaloids formed by photodimerization reactions of the cinnamoylcocaine molecules in the coca plant. Ten stereoisomeric forms of the truxilline molecule are known to occur in nature. Analysis of more than 5000 authentic cocaine samples by the STRL since 1997 has revealed that the total truxilline content of cocaine may vary from less than 1% up to ~25% by weight relative to the cocaine. A number of parameters play a role in determining how total truxilline content varies. Generally it has been found that there is a strong correlation between species and the truxilline concentration which in turn leads to a correlation between geographical origin of the leaf and truxilline content. Truxilline alkaloids are determined by the AIDIP using a complex analytical technique involving several organic reactions and gas chromatography–mass spectroscopy.

**Cocaine Signature 3—occluded solvents**

As with heroin, the solvents employed during the conversion of cocaine base to cocaine hydrochloride provide much information about where processing occurred. The process involves cocaine base being dissolved in one solvent and hydrochloric acid in another. The two solutions are mixed and the cocaine hydrochloride precipitates, is filtered and dried. Traces of the solvents used may be detected easily using the same technique as is used for heroin. The solvent combinations used in Colombia are markedly different to those employed in Peru or Bolivia which in turn are different from each other.

**Cocaine Signature 5—stable isotope ratios**

The ratio of the stable isotopes of carbon and the stable isotopes of nitrogen also correlate with geographic origin of the plant. The isotopic composition of cocaine present in the plant may be fixed during biosynthesis. Isotope ratios measured in different cocaine samples will reflect differences in species and within the same species and variant, differences in environmental conditions. Such environmental influences include soil conditions, microbial N₂ conditions, humidity, altitude and water stress. Determination of the carbon and nitrogen stable isotope ratios is a complex task but one that provides a large amount of important data regarding origin. When taken in combination with the other cocaine chemical signatures it is a powerful technique.
4. Amphetamine type substances (ATS)

Within Australia methylamphetamine and 3,4-methylenedioxymethylamphetamine (MDMA or ‘Ecstasy’) are the ATS of most concern. At present methylamphetamine supply is dominated by domestic production while the majority of MDMA is being produced in Western Europe and the Southeast Asian/Oceania region. Developments in South East Asia have also seen a rise in methylamphetamine production and Australia has been identified as one potential market.

MDMA is a fully synthetic drug and is usually prepared from the precursor 3,4-methylenedioxyphenyl-2-propanone (3,4-MDP-2-P) via a number of synthetic routes. There are actually many synthetic pathways available but at present only a comparative few are used. 3,4-MDP-2-P itself is prepared usually from safrole, isosafrole or piperonal, again by a variety of synthetic pathways. The major source of precursor chemicals for MDMA production throughout the world is thought to be the Chinese chemical industry.

Methylamphetamine is also a fully synthetic drug which may be produced by utilizing any of a multitude of synthetic pathways. Currently the major precursors for domestic methylamphetamine production are pseudoephedrine or ephedrine illegally imported into Australia or pseudoephedrine and ephedrine that have been diverted from legitimate industrial use. A lesser source is the so-called ‘pseudo-runners’ who purchase or steal pseudoephedrine in its various forms from pharmacies across Australia. The most popular synthetic route employed by clandestine laboratory operators in Australia at the time of writing involves the reduction of pseudoephedrine or ephedrine using either red phosphorus and hydriodic acid or hypophosphorus acid and iodine. Another procedure involves the reduction of either ephedrine or pseudoephedrine using lithium or sodium dissolved in liquid ammonia. This route is quite common on the west coast of Australia.

The major aim of the AIDIP with respect to methylamphetamine and MDMA is to determine the synthetic route used and the precursor chemicals involved. This represents valuable intelligence to law enforcement and government policy formulators as it can assist in the regulation of legitimate industrial chemicals that might otherwise be diverted for use in clandestine illicit drug operations. The same approach is used for both drugs and currently involves two chemical signatures as well as the physical ‘Signature 4’.

**ATS Signature 1**

When either MDMA or methylamphetamine is produced as a result of criminal activity little or no quality control procedures are employed. The result is that in most cases a range of manufacturing by-products is formed. Identification of these by-products can assist in determining the synthetic pathway and precursor chemicals. The technique used by the AIDIP to identify these by-products is a liquid–liquid extraction followed by gas chromatography–mass spectroscopy. It is based on the same method used by several European nations and the United States and allows data to be shared internationally (van Deursen et al. 2005; Lock, personal communication).

**ATS Signature 2**

The next area of investigation is the elemental analysis of the drug by Ion Coupled Plasma Mass Spectroscopy (ICPMS). Because most of the synthetic pathways to illicit drugs employ catalysts such as platinum oxide, palladium chloride or Raney Nickel or reagents such as sodium borohydride, mercuric chloride and red phosphorus, a knowledge of the trace elements present in either MDMA or methylamphetamine can be revealing and informative.
5. Data manipulation

Because an endeavour as large as the AIDIP necessarily generates a huge amount of data, it is essential that it be stored efficiently and in a way that allows it to be easily used for extracting information. To this end a database has been custom built to suit the AIDIP’s unique chemical requirements. This database has now matured into an excellent tool. It is capable of uploading all instrumental raw data for each of the chemical signatures described. Once the data are residing in the database they are then subjected to various mathematical routines to process them into useful information. For instance, as opiate alkaloid data are transferred from a capillary electrophoresis instrument in the laboratory to the database an algorithm is applied which automatically calculates the geographic origin of the heroin. This algorithm was constructed based on empirical evidence obtained from thousands of authentic heroin samples. Similar mathematical routines operate in the cocaine and amphetamine modules of the database.

At the same time there remains an onus on the AIDIP to work on initiatives to translate scientific data into information that law enforcement investigators and intelligence analysts can use. Work is now focusing on a system that will bring the physical and chemical aspects together. Accomplishing this will allow easier monitoring of trends or identification of unusual seizures based on the physical aspects of the packaging materials and the illicit drugs themselves as well as their chemical identity, purity and profile.

6. The future?

The AIDIP is a national programme, involving Federal agencies, looking at the origin and synthetic chemistry of drugs seized at our border. To make it a truly national programme it must evolve to include the States and Territories of Australia. While we now know quite a lot about drugs that are seized at the Australian border we know very little about the drugs that evade detection and end up on the streets of our major capital cities and smaller country towns. A coordinated effort is required by both Federal and State agencies to achieve this outcome and this alone is likely to see major changes for the current AIDIP.

Yet the programme cannot only focus inward. The obvious story from the border is that drugs will continue to traverse the journey between production site and the Australian consumer. One way that the AIDIP can work to make this trip more difficult is to engage with regional partners and develop complementary forensic capabilities within jurisdictions that commonly either contain production centres or act as transshipment points. Just as information from the States and Territories would clarify the picture post-border, information from neighbouring countries would help establish the flow of drugs and the spread of the network and its market in the broader region.

Ultimately such information will lead to more knowledgeable and evidence-based decision-making, whether by investigators working on a specific case or an intelligence analyst recommending strategic policy options. Future challenges are evident and opportunities for developing the capacity of forensic drug profiling exist at home and abroad. In a dynamic field, AIDIP must evolve if it is to fulfil its responsibility of providing scientific evidence to assist in the administration of the law as it relates to illicit drugs.
References