



DRUG CHECKING

AS A HARM REDUCTION INTERVENTION

Evidence Review Report
December 2017

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About the BC Centre on Substance Use

The [BC Centre on Substance Use \(BCCSU\)](#) is a provincially networked resource with a mandate to develop, implement, and evaluate evidence-based approaches to addiction and substance use. Building on the extensive efforts of the BC Centre for Excellence in HIV/AIDS and the Urban Health Research Initiative, the BCCSU's vision is to transform treatment of substance use in BC by translating research into education and evidence-based care guidance. By supporting the collaborative development of evidence-based treatment policy, guidelines, and standards, BCCSU will improve the integration of care across the continuum of substance use programming and policy, thereby serving all British Columbians.

The BCCSU is founded on the values of: advancing, seeking and sharing of knowledge; collaboration at all levels across the continuum of care; empowerment of individuals, families, and communities; excellence and quality through innovation and evidence; advocacy for positive policy change, reduction of stigma and support for patients and families; and mutual respect and equity for all members of the community and their contributions.

In order to provide leadership in treatment system for addiction and substance use and to help reach all British Columbians who need these services, the BCCSU will integrate activities of its three core functions:

1. **Research and Evaluation** – Lead an innovative multidisciplinary program of research and evaluation activities to guide health system improvements in treatment and care for addiction and substance use.
2. **Education and Training** – Strengthen education activities that address addiction and substance use across disciplines, academic institutions, and health authorities, and train the next generation of leaders in the field.
3. **Clinical Care Guidance** – Develop and implement evidence-based clinical practice guidelines and treatment pathways.

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List of Acronyms

ANKORS

AIDS Network Kootenay Outreach and Support Society – a nonprofit organization that provides pill testing and other services in BC

CE

Capillary Electrophoresis

CE-MS

Capillary Electrophoresis-Mass Spectrometry

CE-UV

Capillary Electrophoresis-Ultraviolet Spectrometry

CE-MS

Capillary Electrophoresis- Mass Spectrometry

DIMS

Drug Information and Monitoring System – the Dutch drug checking system

FTIR

Fourier-Transform Infrared Spectrometry

GC

Gas Chromatography

GC-MS

Gas Chromatography-Mass Spectrometry

HPLC

High Performance Liquid Chromatography

HPLC-MS

High Performance Liquid Chromatography-Mass Spectrometry

HPLC-UV

High Performance Liquid Chromatography-Ultraviolet Spectroscopy

HPLC-UV-Vis

High Performance Liquid Chromatography-Ultraviolet Spectroscopy and Visual Spectrum Spectroscopy

IMS

Ion-mobility spectrometry

LSD

Lysergic Acid Diethylamide

MDMA

Methylenedioxymethamphetamine

MS

Mass Spectrometry

NEWIP

Nighlife Empowerment and Well-being Implementation Project

NPD

Nitrogen-Phosphorous Detection

PMA

Paramethoxyamphetamine

PMMA

Paramethoxymethamphetamine

SINTES

National Identification System for Drugs and Other Substances – French drug checking model

TEDI

Trans European Drug Information Project

TLC

Thin Layer Chromatography

UV

Ultraviolet – also refers to UV spectrometry

Note on Scope

The British Columbia Centre on Substance Use was commissioned by the British Columbia Ministry of Health to conduct a detailed review of literature pertaining to techniques, implementation models, and the benefits and risks associated with drug checking as a harm reduction intervention, with particular focus on existing drug checking services in other jurisdictions such as Western Europe.

Accordingly, the present evidence review report provides a description and evaluation of existing drug checking technologies and services in other countries with reference to the available literature in this field. The selection and review of evidence have been conducted in the context of BC's needs in the context of the current illicit drug overdose crisis; however, discussion of provincial resource implications and current capacities are beyond the scope of this document.

Background

The rapid growth of the psychoactive drug market and the associated increase in substance use-related morbidity and mortality in recent decades have prompted a gradual shift towards harm reduction interventions in Canada and the world.¹ The term ‘harm reduction’ denotes “policies, programmes, and practices that aim primarily to reduce the adverse health, social, and economic consequences of the use of legal and illegal psychoactive drugs without necessarily reducing drug consumption.”² This concept encompasses evidence-based interventions such as pharmacological treatments (i.e., opioid agonist treatments), distribution of harm reduction supplies through needle and syringe programmes, and supervised injection facilities, and other overdose prevention and rescue measures.¹

In British Columbia, the public health emergency declared in 2016 in response to the increase in illegal drug overdose deaths highlights the need to expand the province’s suite of harm reduction services. The overdose crisis is attributed in large part to the emergence of bootleg fentanyl, a highly potent synthetic opioid illicitly manufactured and used to replace heroin and other opioids (e.g., through counterfeit pills). Provincial surveillance data indicate that the proportion of illegal drug overdose deaths involving fentanyl has increased from 5% in 2012 to approximately 67% in 2016.³ Fentanyl was detected in 81% of all reported overdose deaths between January 1 and August 31, 2017.³ Figure 1 presents the trend of illicit drug overdose deaths in BC in the span of the last decade with and without fentanyl detected. This graph demonstrates that fentanyl accounts for the sharp increase in overdose deaths since 2012, as the number of overdose deaths that did not involve fentanyl has remained fairly stable.. This influx of new and highly potent substances necessitates the consideration of all possible harm reduction measures, including directly informing people who use illegal drugs about substances they have acquired and providing public health and safety officials with a means of monitoring the rapidly evolving range of psychoactive drugs circulating in illicit markets in a factual and timely manner.

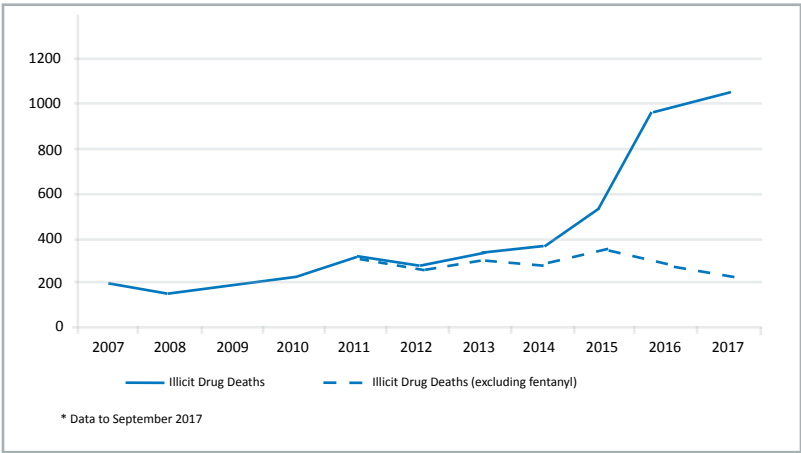


Figure 1. Unintentional overdose deaths including and excluding Fentanyl, 2007-2017
Adapted from BC Coroners services. Illicit Drug Overdose Deaths in BC, January 1, 2007-August 31, 2017. September 7, 2017.

Drug Checking as a Harm Reduction Intervention

The term “Drug Checking” refers to a service that enables people who use drugs to chemically analyze their street-acquired drugs and receive individualized and fact-based consultation regarding the contents, and the associated risks, of compounds detected in their samples.⁴ Drug checking can be conducted using a range of technologies many of which are typically employed for forensic tests, either at a stationary laboratory where samples are dropped off or shipped for analysis, or at an on-site location where clients may bring samples for checking before consumption. Some drug checking services incorporate a brief counselling component while allowing service users to maintain their anonymity, often serving as an initial point of contact with other health information and services.

The concept of drug checking was introduced in the early 1990s as a new strategy to reduce harms associated with the use of novel and sometimes hazardous synthetic psychoactive drugs at party settings across Europe.⁵ The first harm reduction-focused drug checking programme was established in the Netherlands in 1992 when the Dutch government commissioned the Drug Information and Monitoring System (DIMS) to monitor the country’s recreational drug markets with respect to dose, composition, adulterants, and availability.⁵ Different modifications of the Dutch drug checking system were established in many European countries including France, Switzerland, Spain, and Portugal during the 1990s and 2000s.⁶ In addition to communicating analysis results to service users, these drug checking networks maintain up-to-date databases of new and existing psychoactive drugs. These data serve as a guiding factor in policymaking and harm reduction activities on a population scale.^{5,6}

Though drug checking networks in Western Europe remain the largest and longest running in the world, similar services have emerged in Australia, the United States, and Canada. The vast majority of these services focus exclusively on drugs used in party settings (e.g. ecstasy, LSD, and cocaine) and there is as yet no evidence regarding the efficacy of drug checking as a harm reduction intervention in the context of regular non-medical opioid use. As quality control over production and distribution of illegal drugs does not exist in the context of the current international drug control regime, and consumer safety protections are thereby not extended to people who use illegal drugs, drug checking services offer a means of accountability in the illegal drug market that otherwise does not exist. It is reasonable to hypothesize that drug checking services can help shift and stabilize the illegal drug market towards a less toxic inventory, since consumers who are able to avail themselves of information about what they are purchasing would be able to avoid patronizing dealers who sell adulterated/contaminated products.

Drug Checking in British Columbia

Health Canada's Drug Analysis Service (DAS) laboratories have conducted routine street drug testing for decades at a number of locations across Canada, including the regional laboratory in Burnaby, BC. However, these labs exclusively support public safety systems, analyzing samples of contraband substances seized by Canadian police forces and the Canada Border Services Agency when they have seized contraband substances likely to be used as evidence in criminal prosecutions.⁸ There is no harm reduction element to the DAS lab services, and, thus, no mechanism to enable individuals to submit a sample for analysis. Even the public health surveillance potential of the DAS lab service is underutilized in the absence of a routine comprehensive reporting to health systems partners, although the development of a National Drug Observatory commissioned by Health Canada may change this.⁸

Drug checking was first introduced to British Columbia as a harm reduction intervention in the late 1990s, when young people involved in the electronic dance music scene began to organize and provide peer-based colorimetric reagent testing of "ecstasy" pills at all-night dance-parties and festivals. At the time, the provision of these services was met with opposition by law enforcement officials. Nevertheless, a 2005 British Columbia Ministry of Health policy document included street drug testing and early warning systems as an example of harm reduction strategies that "are an integral part of a comprehensive response to problematic substance use."¹⁰

An example of a long running drug checking service operating in BC is the annual work undertaken by AIDS Network Kootaney Outreach and Support Society (ANKORS), which has provided on-site drug checking at the Shambhala music festival since 2003. This service offers colorimetric reagent tests alongside other harm reduction supplies in a drug checking tent at the festival venue. Between 2003 and 2015, the organization conducted over 17,000 drug checking tests at this multi-day festival.¹² Since 2016, ANKORS has expanded its onsite drug checking technologies by adding a Raman spectrometer and mobile thin layer chromatography kits to accommodate increasing demand. In 2017, ANKORS piloted the deployment of a gas chromatography-mass spectrometry (GC/MS) machine at Shambhala, although results of its performance are not yet available.

In the context of the current public health emergency in British Columbia, a pilot drug checking project was established at Insite, Vancouver's supervised injection facility, in July 2016.¹² The aim of this programme is to inform Insite service users of the presence of fentanyl in the drugs they intend to use. Nurses provide consumers with test strips and offer simple instructions for diluting and testing their drugs. The results of tests are posted daily for all patrons to view.¹³ Between July 2016 and August 2017, more than 1,400 samples were checked and 80% of them were positive for fentanyl.¹³ This programme is novel in its focus on people who inject drugs, as well as its use of a dipstick technology originally designed for detecting fentanyl in urinalysis. As such, issues regarding the use of a urine dipstick in drug solution remain, and it is unclear to what extent such use may result in false positive or negative results. An evaluation of this programme is currently underway.

The STS Pain Pharmacy in Victoria offers a similar service to clients who use drugs.^{14,15} Within the past year, roughly 150 different drug samples have been tested for fentanyl at this location using the same test strip method, and 90% of the results were positive.¹⁵ This method is not capable of quantifying the fentanyl detected in a sample; thus, given the pervasive presence of fentanyl in the tested samples, the service may be more useful to occasional and non-opioid drug consumers than to those who use opioids regularly and face the risk of overdose on a daily basis. To address this consequential gap, the STS pharmacy has partnered with the chemistry department at the University of Victoria to develop a compact and

inexpensive device that uses UV light to detect and quantify fentanyl, and potentially its analogues, on-site. In addition to facilitating quantitative on-site drug checking across the country, the long-term goal of the project is to build a comprehensive library of samples that can be shared with other harm reduction facilities and health authorities.¹⁵ This project is funded by the federal government's Natural Sciences and Engineering Research Council of Canada and is currently in its early phases.¹⁴

It should be noted that in Canada drug checking currently requires an exemption under the Controlled Drugs and Substances Act (CDSA) to allow service staff to offer clients the means of drug checking without handling the sample themselves.¹⁶ The exemption requirement and the legal ambiguity surrounding drug checking services have been cited as barriers to implementing and evaluating drug checking as a harm reduction measure.^{17,18} However, in December 2016 the federal government introduced a new Canadian Drugs and Substances Strategy which restored harm reduction as a core pillar of Canada's drug policy. Accompanying this new strategy was the tabling of Bill C-37, legislation that proposes to amend CDSA to simplify the process of acquiring exemptions for medical purposes in relation to activities within supervised consumption sites involving illegally obtained controlled substances, which could include drug checking.^{18,19}

This report provides a review of available technologies and implementation models for drug checking and discusses the efficacy of the service as a harm reduction intervention in the context of British Columbia's substance use trends.

Review Methodology

The evidence base for this review was compiled through two separate search processes for drug checking service models and technologies. An initial literature search was conducted in PubMed and Google Scholar using the search terms 'drug checking,' 'drug testing,' 'pill testing,' and 'pill checking.' The reference list of each selected article was subsequently reviewed for additional relevant studies. In the process of reviewing the studies selected from the initial search results, the names of technologies used in drug checking were documented and used as search terms in a separate literature search. This was also followed by a review of the reference lists of selected articles.

In view of the limited volume of evidence on the efficacy of drug checking, literature search results were supplemented by consulting grey literature and contacting experts in the field.

Section One: Drug Checking Technologies

The analytical capacity of the technologies presented here is well-documented in pharmaceutical and law enforcement fields. However, drug checking presents a somewhat distinct set of concerns with respect to portability, cost, ease of sample preparation by untrained individuals, speed, and capacity for detecting new compounds. Below, their technical features are reviewed to assess their suitability for use in drug checking services. Table 1 offers a comparative summary of the technology specifications presented in this section, with a focus on drug checking for opioids.

Table 1. Comparative summary of device specifications

Technology	Detect a wide variety of compounds	Ability to detect fentanyl and other opioids	Ability to detect multiple compounds at once	Specificity	Sensitivity	Quantitative analysis	Can identify unknown compounds	Speed per sample	Cost	Suitable drug checking settings
Colorimetric Reagent Testing ^{6,17,20-23}	Moderate	Low	Low	Low	Low	No	No	<6 min	\$	Stationary, Mobile
Fourier-transform Infrared Spectroscopy (FTIR) ²⁴⁻²⁷	High	Moderate	High	High	High	Low	No	<2 min	\$\$	Stationary, Mobile
Thin Layer Chromatography (TLC) with UV detection ^{6,20,23-25}	Moderate	Weak	Moderate	Moderate	Moderate	Low	No	30 min, multiple at once	\$\$	Stationary
Capillary Electrophoresis (CE) with UV detection ^{23,24,26-28}	High	Moderate	Moderate	Moderate	Moderate	Moderate	No	<2min*	\$\$	Stationary
High Performance Liquid Chromatography (HPLC) with UV detection ^{6,17,23,24,29-31}	High	High	High	High	High	High	No	15 min	\$\$	Stationary, Mobile
High Performance Liquid Chromatography (HPLC) with MS detection ^{6,17,24,32-34}	Highest	Very high	Very high	Very high	Highest	Highest	Yes	7.5 min*	\$\$\$\$	Stationary**
Gas Chromatography (GC) with MS detection ^{6,17,24,33,35,36}	Very high	Very high	Very high	Very high	Very high	Very high	Yes	14.5 min*	\$\$\$\$	Stationary
Ion Mobility Spectrometry ³⁷⁻⁴²	Moderate	Moderate	Moderate	Low	High	Moderate	No	<1 min*	\$\$	Stationary, Mobile
Ion Mobility with MS detection ³⁷⁻⁴¹	High	High	Very high	High	Very high	High	Yes	20-30min*	\$\$\$\$	Stationary

*These durations are estimates based on machine-specific run times alone, and do not include collection, preparation, report generation, or consultation.

** While this technology has also been used in mobile lab-in-a-van settings, but the equipment is not considered portable.

Colorimetric Reagent Tests

Colorimetric reagents are chemical liquids each capable of indicating the presence of a different group of drugs by a change of colour upon exposure to the target compounds. To test a sample, a few drops of a reagent are added to a small amount of crushed pill or powder. The resulting colour can be compared to the colour chart or swatch provided by the reagent manufacturers to identify the present compound. This process is typically repeated using different reagents on small amounts of the same sample. The results of each successive test are used to identify or eliminate a set of possible adulterants and to select the next reagent. The capacity of colorimetric testing is limited to ascertaining the presence of a known drug according to the reference colour chart; this method is unable to identify new compounds or quantify the contents of a sample. Law enforcement has utilized this method for the rapid testing of drug samples in the field for many years.²⁰⁻²² Over the past decade, this method has been the most widely used for on-site drug checking as a harm reduction intervention.^{5,17,23,47}

Technical

Selectivity: MDMA, PMA, PMMA, Methamphetamine, Morphine, Codeine, Oxycodone, Heroin, and Cocaine are just a few of the common illicit drugs that have been identified using colorimetric testing.^{17,22}

Currently there is a colorimetric reagent test for fentanyl produced by NARK® II Sequential Testing System, but it is only available to law enforcement and has never been used in drug checking services.

Sensitivity: Colorimetric reagent tests are the least sensitive of all drug testing technologies. This method is error-prone as the vast majority of samples contain multiple reactive substances; multiple colour changes at once render the visual interpretation of results a subjective and inexact task.^{17,20,21} In samples with mixtures of two substances, it was reported that both substances were correctly identified in only 11% of the samples, although this is highly dependent on which compounds are present.⁴⁷ However, smart phone applications have been developed to aid the accurate interpretation of results.⁴⁸

Speed: Colorimetric reagent testing is the most rapid of all drug checking tests, as color changes may be seen almost instantaneously. The time to fully test a sample is most likely 3-6 minutes. This may vary slightly based on the number of reagents used.²⁸

Possible settings

Colorimetric reagent testing has been used for on-site drug checking in multiple stationary and mobile venues. Examples include the Shambhala Music Festival in BC, and on-site drug checking in the Netherlands.^{5,17,23,47}

Cost

Colorimetric reagent testing costs less than \$0.50 per test on average.¹⁷

Summary of advantages and disadvantages

Due to its low cost, speed, portability, and ease of application, colorimetric reagent testing has been widely used for the on-site checking of pill scrapings from party drugs. However, this is a particularly limited method in terms of accuracy and range. Also, there is little evidence of this test being used on liquid or solid state samples or for detecting fentanyl. There are conflicting views on whether this drug checking method is beneficial to people who use drugs, given the possibility that a false negative may result in a false sense of security.⁴⁹ In various countries, colorimetric testing is used for preliminary analysis in tandem with other, more robust drug checking methods.⁵

Due to its low accuracy, lack of capacity for quantitative testing, lack of sufficient precedent in detecting fentanyl and other opioids, colorimetric reagent testing used on its own may not be well suited to BC's current needs. Appendix B provides tables outlining the advantages and disadvantages of all reviewed technologies.

Fourier-Transform Infrared Spectroscopy (FTIR)

An established chemical analysis technique in food and pharmaceutical industries and forensic chemistry, FTIR works by shining different wavelengths of infrared light onto the sample and measuring the amount of infrared radiation it absorbs at each wavelength. Since each compound has a unique absorption behavior, this information is used to mathematically model its unique chemical structure.²⁴⁻²⁶ Commercial FTIR equipment includes the software that produces the sample's absorption profile and compare it to the compounds in a database to find a match.^{27,50} While the body of evidence supporting the use of this technique for analyzing illegally manufactured psychoactive substances is relatively limited, the accuracy of published results, combined with the ease and speed of sample preparation and testing, has prompted the use of FTIR as a primary onsite drug checking method by a UK service.²⁷

Technical

Selectivity: FTIR has been successfully used to identify a wide range of compounds including cocaine, MDMA, heroin, and a variety of designer drugs and common fillers.²⁴⁻²⁶ However, there is little evidence on its ability to distinguish between opioids with similar chemical structures. FTIR is not suitable for identifying unknown compounds.²⁷

Sensitivity: This method has been reported to easily identify compounds with 10% concentration by weight.^{24,27}

Speed: Speed is one of the outstanding features of this device. The runtime of the average FTIR test is approximately 1-2 minutes.⁵⁰

Possible settings

The FTIR equipment is compact and portable and can be used in both mobile and stationary setting.^{27,50} This device is suitable for high traffic situations due to its speed and ease of operation.

Cost

The estimated cost of Bruker's Alpha FTIR spectrometer is approximately CA\$50,000 (www.bruker.com/optics), which includes software and library databases to match spectrograph readings with those of known illegal drug samples. Providing a 10-year warranty for the device, the manufacturer cites durability and low operation cost as among its key advantages.⁵⁰

Summary of advantages and disadvantages

Due to its speed and portability, FTIR is ideally suited for onsite drug checking in high traffic situations. This technique is also far more versatile and accurate than other methods used for rapid onsite drug checking, such as colorimetric tests, as it can identify multiple compounds at once without relying on subjective result interpretation.^{25,50} FTIR requires no sample preparation and can be operated with comparatively minimal training. FTIR is a non-destructive testing method suitable for samples in both solid and liquid phase; samples can be restored to the client or used for further testing once analysis is completed.^{24,25}

While FTIR provides some information regarding the approximate concentration of each detected compound, it is not suitable for quantitative analysis without the addition of analytical accessories. This device is not capable of identifying unknown compounds. Due to the FTIR device's possible limitations in detecting substances present in low concentrations, it is recommended that a fentanyl immunoassay test strip be used concurrently on all samples tested with FTIR as a point-of-care technology.

Appendix B provides tables outlining the advantages and disadvantages of all reviewed technologies.

Thin Layer Chromatography (TLC)

Thin Layer Chromatography (TLC) is used to separate different chemical compounds. After the compounds have been separated, but while they are still stuck on the surface of the TLC apparatus, which is similar in appearance to a slip of paper, different dyes are applied to the apparatus. Photographs of the TLC apparatus are then taken under regular and ultraviolet (UV) light.²⁹ The colours and the positions compounds in relation to each other on the TLC apparatus form unique patterns. The compounds in the sample are identified by comparing these patterns to those of known reference drugs. This technique is generally not used to quantify compounds or to identify unknown substances.^{23,38,39,51} TLC has been used in a variety of drug checking services (e.g., Netherlands, Spain, and Portugal).^{5,23,28,29} It is also commonly utilized in law enforcement and the pharmaceutical industry.^{20-23,33,39,51}

Technical

Selectivity: TLC is able to identify a wide range of compounds, including amphetamines, heroin, morphine, and cocaine.²³ However, the ability to analyze highly similar analytes of these compounds is limited, and there have been reported instances TLC failing to differentiate between synthetic opioids.²⁹

Sensitivity: TLC is more sensitive than colorimetric reagent testing, especially when testing drug samples that have a mixture of compounds. However, TLC has been shown to be less sensitive than gas chromatography (reviewed below).⁵¹ Similar to colorimetric reagent testing, TLC partially relies on the interpretation of colour results and, thus, is not immune from human error, especially in the case of complex mixtures or highly diluted compounds.³³

Speed: The run time of this test is approximately 30 minutes; however, given the low equipment costs, it is possible to run several samples at once using multiple devices.²⁸

Possible settings

The simple methodology and equipment needed for TLC means that the analysis could generally be performed in any setting, including mobile and stationary drug checking labs.

Cost

TLC equipment is relatively inexpensive and the process requires minimal training.²⁸ This test is principally performed with visual light and UV detection, but, as with gas chromatography (GC) and high performance liquid chromatography (HPLC), a mass spectrometer can be used instead of UV light for detection after the separation process is completed.³⁹ This would yield more accurate results than light detection alone, but would increase costs significantly.

Summary of advantages and disadvantages

TLC is more sensitive than colorimetric testing. This method requires little equipment and has high potential for effective mobile drug checking applications that could be implemented in a wide range of settings. However, TLC is slower and less sensitive than the other separation-based technologies (i.e., HPLC and GC) and is often used in conjunction with gas chromatography-mass spectrometry (GC-MS) to substantially increase the accuracy of results.^{29,39}

TLC is suitable for the detection of known compounds, and relies on a reference library to identify samples.

TLC may not be suitable for high-traffic settings due to its long run time. Appendix B provides tables outlining the advantages and disadvantages of all reviewed technologies.

High Performance Liquid Chromatography

High performance liquid chromatography (HPLC) has been used in tandem with either mass spectrometry (MS) or UV spectrometry (UV) for drug checking purposes in the past.^{5,23,28,34,35} Though the pool of available evidence for drug checking is small, these methods have been used in the pharmaceutical industry and law enforcement for many years and are well established.^{33,36-39,52,53} HPLC separates different compounds, which are then detected by either MS (mass to charge ratio) or UV (using light absorption) detectors. Both HPLC-MS, and HPLC-UV identify and quantify individual compounds from mixtures.

Technical

Selectivity: Of the methods presented here, HPLC-MS can identify the broadest spectrum of unique compounds. Some drug checking services have used HPLC-MS to discern new substances that are not identifiable with other technologies. This process is more complex, resource-intensive, and time consuming than identifying known compounds, but could be highly beneficial for identifying new and potentially harmful adulterants in street drugs.^{23,38} On the other hand, HPLC-UV can only identify known compounds based on a reference library.²⁸ HPLC-MS tends to have much higher specificity than HPLC-UV,³² though the latter is also one of the superior methods in terms of selectivity.²⁹

Sensitivity: HPLC-MS has been reported to detect impurities as low as 1 ppm by weight in heroin.⁵² It is important to note that sensitivity is greatly reduced when analyzing unknown compounds; therefore, new drugs that may be present in low but clinically meaningful concentrations may be missed.³⁸ HPLC-UV-Vis has lower sensitivity than HPLC-MS, but is still quite powerful.³⁶

Speed: Total run time of 7.5 minutes per sample has been reported for on-site drug checking with HPLC-MS; however, depending on programme design, results may take longer to reach the customer (see Possible Settings section below).⁵ HPLC-UV has a reported total run time of less than 15 minutes per sample when used for on-site drug checking, including questionnaire and disclaimer administration.³⁵

Possible settings

HPLC-UV or HPLC-MS has been implemented in both stationary and real-time mobile drug checking services in Austria and Switzerland.^{5,35}

Cost

The high cost of the HPLC-MS equipment may be prohibitive. The cost for mass spectrometers varies based upon the size and settings of the machine. For example, the DART QDa Mass Spectrometer (<http://www.ionsense.com>) is portable and capable of real time analysis. This machine's quoted price is between \$100,000 and \$130,000 (as quoted from conference call on 11/22/16). Stationary models with higher sensitivity and specificity can range up to \$500,000. UV detector equipment is less expensive. Both methods require highly trained laboratory technicians for sample preparation, running the equipment, and result interpretation.

Summary of advantages and disadvantages

HPLC-MS is highly adaptable for new psychoactive substances without significant modification, whereas HPLC-UV is not able to perform this function. Both HPLC-MS and HPLC-UV are able to quantify compounds. Additionally, the amount of sample required for testing is very small, which may increase the likelihood of consumers using this service.²⁸

As the machine can only analyze one sample at a time, these methods may not be feasible for music festivals or other high-traffic settings. Also, the loading of a sample may prove challenging if technicians are not allowed to handle the sample for legal reasons, as was the case in a recent BC music festival, though this issue can be resolved with a federal exemption.¹⁷ These methods would be more suitable for a stationary settings such as a drop-off/mail-in sample service where the samples would be tested

in a laboratory. With access to the proper portable equipment, both methods would be feasible as mobile services. Appendix B provides tables outlining the advantages and disadvantages of all reviewed technologies.

Gas Chromatography Mass Spectrometry

Similar to HPLC-MS, gas chromatography mass spectrometry (GC-MS) involves the separation of compounds by gas chromatography, followed by detection using a mass spectrometer (measuring mass to charge ratio). This method of identification and quantification of compounds has been widely used for many years in both the pharmaceutical industry and law enforcement.^{33,37,39,40,53} Evidence for the use of GC-MS in drug checking is limited.

Technical

Selectivity: GC-MS is capable of identifying unknown compounds. However, the range of compounds it can identify is limited compared to HPLC-MS.^{37,54} This is because compounds must be readily able to evaporate and be stable at high temperatures.

Sensitivity: The minimum detection limit for GC-MS varies between methods and has been reported as 3 ppm for impurities in cocaine and 2ppm for impurities in heroin.⁴⁰ GC-MS is much more sensitive than HPLC-UV but less so than HPLC-MS.⁵³

Speed: Similar to HPLC-MS, GC-MS was used in the Netherlands with slightly longer run time of 14.5 minutes per sample.

Possible settings

To date, there are no known examples of GC-MS being used as a portable method for drug checking. The Netherlands utilizes this method in their stationary sample testing service, where samples are sent in and the results are available for the consumer within one week. This method is only operable by highly trained laboratory technicians.

Cost

Similar to the HPLC-MS, GC-MS may be prohibitive due to the high cost of equipment.

Summary of advantages and disadvantages

GC-MS is an established instrument for impurity profiling for heroin and cocaine.⁵³ The amount of sample required for testing is quite small, potentially increasing the likelihood of consumers using this service.^{28,53} GC-MS sample preparation is generally more complicated and slower than HPLC-MS, which renders it unsuitable for drug checking in high-traffic settings.³⁴ Additionally, if the goal is to build up a database on new drug adulterants alongside drug checking, GC-MS selects for a smaller range of drugs compared to HPLC-MS. Appendix B provides tables outlining the advantages and disadvantages of all reviewed technologies.

Capillary electrophoresis

Similar to HPLC-UV, Capillary electrophoresis (CE) involves two steps: separation of drug components based on their charge and size as they pass through a capillary, followed by detection (UV or MS).³⁰ MS is able to detect unknown compounds, while UV detectors are not. This method has been primarily used by law enforcement, and has yet to be implemented in a drug checking context. One technique described in the literature rapidly quantifies heroin and identifies impurities using specialized capillaries and UV detection.³¹

Technical

Selectivity: CE has been used to quantify a wide variety of street drugs. However, it is limited by the types of compounds it can detect (neutral, acidic, or weakly basic, and interacts with light).^{30,31} Recently, forensic methods have been developed for the detection of opioid compounds such as fentanyl and carfentanil in heroin samples using capillary electrophoresis-mass spectrometry (CE-MS). Similar to HPLC-UV, CE-UV can only identify known substances.³²

Sensitivity: CE is generally 1-2 orders of magnitude less sensitive than HPLC.³⁰

Speed: The run time for opioid compounds is generally considerably faster using CE compared to HPLC.³⁰ Though CE has not been used for drug checking in the past, some evidence suggests run times could be made shorter than 2 minutes per sample.³¹

Possible settings

Though there are no examples of this method in practice, it could feasibly be adapted as a portable technology similar to HPLC-UV in Switzerland.³⁴ CE is well established in stationary forensic labs as a means of testing confiscated drugs, and could be readily adapted for drug checking on-site, or as a drop-off/mail-in drug checking service similar to the Netherlands.²³

Cost

The advantage of CE over HPLC or GC is the significantly reduced costs, specifically the low volume of reagents required. Overall, the equipment and consumables involved in this method are considerably less expensive than HPLC or GC. However, mass spectrometers continue to be cost prohibitive.^{28,55}

Summary of advantages and disadvantages

Using the UV detector, CE could be implemented in mobile, on-site, or drop-off/mail-in testing, as well as in high volume situations where there are several machines available (i.e., music festivals), due to the speed, low amount of sample required for testing, and lower costs of this method. CE-MS is able to identify new compounds, but it is important to note that CE is 10 to 100 times less sensitive than HPLC, potentially missing compounds present at low but clinically meaningful concentrations.

While CE has been successfully employed in forensic settings to detect fentanyl and carfentanil in opioids, it has not been used in drug checking. Appendix B provides tables outlining the advantages and disadvantages of all reviewed technologies.

Ion-mobility Spectrometry

Ion mobility spectrometry (IMS) is a versatile screening technology that has been used by law enforcement officials to detect a wide range of compounds including narcotics, explosives, and chemical warfare agents.⁴¹ Ion mobility spectrometry detects target compounds by separating the gas-phase ions of a sample based on their size, shape, and charge.⁴² The technique involves using a low electrical charge to propel an ionized gas-phase analyte through a tube of a given length and determining the signature velocity of the ions based on their drift time (the time it takes for an ion to travel through the drift tube and come to contact with the sensing plate at its end).^{42,43} IMS can be coupled with MS and/or other separation-based technologies for enhanced sensitivity and selectivity.^{41,43}

Technical

Selectivity: IMS is predominantly used as a screening tool to detect predetermined target compounds; on its own this technology is unable to definitively identify a wide range analytes, as different ions may have similar drift times.⁴² IMS struggles to identify unique psychoactive substances in mixtures such as street heroin samples.⁴⁶ Similar to GC-MS, IMS is limited in terms of the types of sample it can analyze, as it

requires samples to be volatile. IMS alone can identify compounds based on a reference library and is not suitable for identifying new compounds.⁴³ However, IMS combined with mass spectrometry (IMS-MS) is able to identify new compounds and meet selectivity requirements.⁴³

Sensitivity: High sensitivity is one of the distinct characteristics of IMS; the amount of sample it requires to detect compounds is in the nanogram to picogram range.⁴⁴ Hyphenation of IMS with liquid and gas chromatography helps enhance the sensitivity of these methods even further.⁴²

Speed: IMS instruments have been reported to provide data on the substance composition in 20 to 40 seconds.⁴⁴ However, there are no estimates for the run time of an IMS-MS in the drug checking context, but speed is often cited as an argument for incorporating IMS in hybrid devices.

Possible Settings

Ion mobility scanners can be portable or handheld, which makes them suitable for a variety of settings, but IMS-MS instruments are stationary.^{41,45}

Cost

Partially due to its frequent usage by law enforcement officials, IMS instruments are commercially available at low cost.⁴¹ IMS-MS instruments are more costly, mainly due to high costs of mass spectrometers.

Summary of Advantages and Disadvantages

The advantages of IMS are speed, relatively low cost, ease of sampling and operation, and high sensitivity. These features enable individuals with minimal training to run the tests using very small amounts of the sample and offer basic qualitative results in seconds. However, IMS scanners require reference libraries to identify target compounds, and they are prone to yielding false positives due to the interference of ambient ions that have similar mobility to target ions.^{43,45}

The limitations of IMS can be addressed by coupling this technology with mass spectrometry; IMS-MS can detect and characterize a wide range of new and existing analytes, including isomeric compounds that cannot be characterized by MS alone.^{42,43} IMS can also be coupled with other separation-based techniques (i.e., gas and liquid chromatography) for superior sensitivity and selectivity. However, more research is required to develop and assess these hybrid devices for the purposes of drug checking.⁴² Appendix B provides tables outlining the advantages and disadvantages of all reviewed technologies.

Other Potential Technologies

Although the available literature on Raman spectrometry and enzyme immunoassays was not sufficient for inclusion in this review, these methods merit mention as they are the focus of novel drug checking projects currently underway in BC.

Raman spectroscopy uses monochromatic light, or a laser, to identify the molecules in a sample. As the laser interacts with the different substances in the sample some photons gain energy and others lose energy as per the inherent characteristics of the molecules present. This allows a target compound to be identified by observing its vibrational 'fingerprint'.⁵⁶ Although Raman spectrometry has not been widely used for drug checking, recent literature reports successful instances of its use to detect a range of psychoactive substances including heroin, cocaine, morphine, and methamphetamines.^{56,58} Raman spectrometry's high selectivity and potential for portability and quantitative analysis have prompted a project in the University of Victoria to develop a compact device for identifying and quantifying fentanyl and other opioids for onsite drug checking.^{14,15}

Enzyme immunoassays have long been used worldwide for urine drug screening.⁵⁹ With this method,

the sample is introduced to a test strip that has been treated with a specific antibody with high affinity for the target compound. If the target compound is present in the sample, its reaction with the antibody causes a change of colour which is recognized as a positive result.⁵⁹ Due to its cost-effectiveness, small size and ease of use and interpretation without training, enzyme immunoassay tests have been chosen for a pilot project that began in July 2016 at Vancouver's Insite where service users are provided with test strips and instructions to check their samples for fentanyl.¹³ In response to promising results after one year of operation, this service has now been expanded to some overdose prevention sites. However, since this method has previously only been used on bodily fluid samples, it may be prone to false positives or false negatives when used directly on drug samples. An evaluation of the accuracy and impact of this method is urgently needed.¹² Nevertheless, there may be some value in making immunoassay test strips available to vulnerable individuals to use for home drug checking, a service model that may reach a broader segment of the sub-population who use illicit drugs. An evaluation of the accuracy and impact of enzyme immunoassay tests and the merits of different service delivery models for this simple drug checking method is urgently needed.¹²

Section Two: A Review of Existing Drug Checking Services

There are over a dozen government-supported drug checking services operating around the world.⁶⁰ By combining a range of sample collection modalities, chemical analysis technologies, and modes of communication with service users and the public, a range of hybrid drug checking services have evolved to inform and complement harm reduction strategies in various communities. This section provides pertinent examples of drug checking models and summarizes the evidence supporting their efficacy as a harm reduction intervention.

Evidence Summary

There are no clinical trials examining the direct impact of drug checking services on the substance use behaviours or health outcomes of service users. In the absence of concrete evidence, steadily increasing patronage and service users' self-reported intentions to discard dangerous drugs based on drug checking results are commonly cited as an indicator the effectiveness of drug checking as a harm reduction intervention.^{5,11,12,17,35,61,62} For example, in a survey of the Checkit! service users in Vienna, two out of three participants reported that they would not use a drug that tests positive for unusual or hazardous contents.⁶³ Similarly, 50% of the drug checking service users surveyed at the 2013 Shambhala festival in British Columbia reported that they would discard the substance if it tested positive for a "high hazard compound" such as PMA.¹¹ Data reported by ANKORS, the organization that provides the drug checking service at the Shambhala, indicates that in the 2015 festival 31% of checked drugs that contained hazardous substances were discarded.¹⁷ Preliminary information from Insite's drug checking pilot project suggests that people who use opioids regularly at the SCS do not tend to dispose of their drugs following a positive result for fentanyl, but they are 10 times more likely to reduce their dose, and those who inject reduced doses are 25% less likely to overdose.¹³

Regardless of whether drug checking can influence the service users' immediate drug use behaviours, studies viewed the opportunity for communication with an otherwise invisible population of drug users as a harm reduction measure.²³ Hungerbuehler et al's 2011 analysis of the sociodemographic features of people who use Zurich's drug checking services revealed that these facilities are the first point of access to any substance use-related service for the majority of service users. Furthermore, studies show that young people who use drugs find factual one-on-one information about their drug purchase more trustworthy than general government-issued information and are more likely to disseminate individually-obtained facts within their social environments.^{23,35}

A dominant and largely evidence-based argument supporting the efficacy of drug checking as a harm reduction program is that it serves as a real-time, consumer-centered surveillance tool facilitating regulatory intervention in the illegal drug market. The Trans European Drug Information Project (TEDI), a shared database of substances analyzed by participating drug checking labs across Europe, has analyzed over 45,000 samples between 2008 and 2013 and provided valuable insight about the emergence of new and dangerous substances in the European drug market on the 'street' level.⁵ These findings have been used for issuing numerous public warnings and taking various harm reduction actions.^{5,60} For example, in the Netherlands the detection of fentanyl in LSD led to a national warning campaign in 2007.²³ Furthermore, it has been suggested that drug users' direct access to knowledge regarding the contents of the substances they purchase may gradually shift the unregulated illegal drug market and make it difficult for dealers to knowingly or unwittingly sell unknown or hazardous substances.^{5,35}

It should be noted, however, that the benefits of public warnings in the literature on drug checking is discussed exclusively in the context of occasional non-dependent drug use and may not be generalizable to those who use drugs daily. In a qualitative study of the impact of public warnings regarding high-potency heroin and increases in fatal overdose rates in Vancouver, BC, Kerr et al (2013) found that these campaigns had little effect on the perceptions and behaviours of participating heroin injectors. Although the warnings had effectively reached their audience, the majority of study participants reported no change in their substance use behaviour, while some reported seeking out the high-potency heroin that had prompted the warning campaigns.⁶⁴

Published evaluations of drug checking found no adverse effect on recreational drug using populations, refuting early arguments that these services may increase drug use in this population by fostering a false sense of confidence.^{49,65} However, the literature also emphasizes that drug checking should be utilized as one component of a more comprehensive harm reduction program tailored to specific target populations. While acknowledging that drug checking is supported by relatively meager evidence at this time, a set of practice standards published by the Nightlife Empowerment and Well-being Implementation Project (NEWIP) funded by the EU Health Programme argues that this service can be an effective addition to existing health promotion strategies if it is designed, implemented, and evaluated according best practice principles.⁴

Examples of Existing Drug Checking Services

Stationary Laboratories

The Drug Information and Monitoring System (DIMS), Netherlands

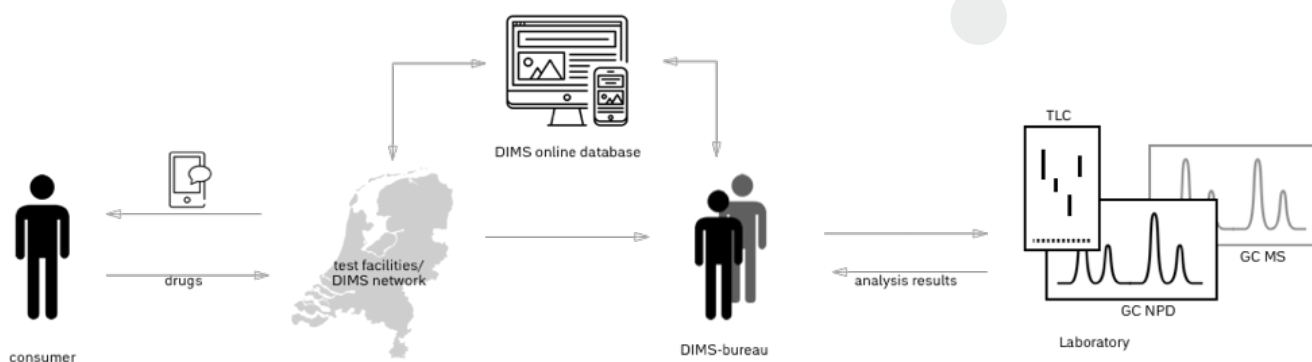
In a comprehensive review article, Brunt and Niesink²³ describe the drug checking process and impact of the country's DIMS in the context of recreational drug use. Established in 1992 by the Dutch Ministry of Health, DIMS consists of a nationwide network of participating harm reduction facilities where clients can anonymously submit their samples for testing. Figure 2 offers a schematic representation of the DIMS system.

The DIMS drug checking algorithm involves both real-time on-site and drop-off laboratory tests. While most of the participating facilities are able to test drugs in either tablet or powder format on-site and offer service users near-immediate results, a few of the locations only function as receiving stations which send collected samples to the DIMS Bureau after assigning a unique code to each package.²³ As the original mandate of this service is to ensure the safety of the country's nightlife, the majority of the samples tested by DIMS are drugs used in this specific context, such as ecstasy, amphetamine (speed), and cocaine.²³

Off-site laboratory analysis procedure: The samples that arrive at the DIMS Bureau undergo a robust set of tests to identify, quantify, and classify known and unknown components. After identifying the chemical components of each sample using Thin Layer Chromatography, Gas Chromatography with Nitrogen-Phosphorus Detection (GC-NPD) is employed to quantify components while confirming the results of the previous step. In case of discrepancies (~10% of cases), Gas Chromatography-Mass Spectrometry (GC-MS) is introduced as a 'tie-breaker'. The total run time of this process is 12-28 minutes, and a wide range of components (e.g., amphetamine; methamphetamine; 3,4-methylene-dioxyethylamphetamine (MDEA); N-methyl-a-(1,3-benzodioxol-5-yl)-2-butamine (MBDB); caffeine; cocaine; and heroin) are identified. The results are electronically shared with the receiving office, which is responsible for informing the consumer. The test results are used to update the DIMS database on a weekly basis; this expanding inventory will facilitate rapid on-site identification of an increasing portion of samples.^{23,63}

On-site drug checking ('office testing'): After recording the physical specifications of the sample, the harm reduction and prevention professionals at the receiving stations use a Marquis reagent test (colorimetric reagent test) to determine if a sample contains any ecstasy-like ingredients, amphetamine, or a hallucinogenic compound. The resulting information is then used to run the sample against the DIMS database for precise identification. 30% of submitted samples have been identified on-site with 99% accuracy, allowing the professionals in receiving stations to immediately communicate the potential harms of the sample to the service user and offer appropriate counsel. The samples that cannot be accurately identified on-site are packaged and sent to the DIMS Bureau. The service users are each assigned a unique number so that they can be informed of the contents of their samples while maintaining their anonymity.^{23,61}

Today DIMS remains the largest and most comprehensive model of consumer-targeted recreational drug checking service for harm reduction purposes; between 2008 and 2013, close to 30,000 drug samples were analyzed by this network.⁶ None of the studies on this system offer specific data on the direct impact of the service on its individual users (e.g., the number of service users who change use behaviour in terms of whether, where, or how much to use upon learning of its specific risks after testing).



credits for iconography: Alexander Smith, lastspark, Bruce Bezerey, pictohaven, Fredrik Edfors (the Noun Project)

Figure 2. schematic representation of the DIMS system.

Adapted from: Brunt TM, Niesink RJ. The Drug Information and Monitoring System (DIMS) in the Netherlands: implementation, results, and international comparison. Drug testing and analysis. 2011

Energy Control, Barcelona, Spain

Energy Control, a nonprofit organization based in Barcelona, Spain, introduced its drug checking service in 2005.⁵ With a central laboratory in Barcelona and receiving stations in Madrid, Palma de Mallorca, and Antequera, the system operates much like DIMS in the Netherlands. However, a distinct feature of Energy Control is the mail-in service whereby service users can mail their samples directly to the Barcelona laboratory for testing. The customer questionnaires and simple instructions for packaging and sending the samples can be downloaded online (see Appendix A). The results are typically sent back to service users within 10 days.

Laboratory analysis at the Barcelona laboratory is conducted using a range of techniques including colorimetric tests, TLC-UV, GC-MS, and HPLC-MS. The service accepts a wide variety of substances for analysis, including heroin. As with many other drug checking services, the sample submission process involves completing a brief questionnaire used to gather information regarding the demographic

characteristics and drug use patterns of service users.

Other examples of mail-in drug checking include Ecstasydata.org in the USA and WEDINOS in Wales (www.wedinos.org).⁶⁰

National Identification System for Drugs and Other Substances (SINTES), France

SINTES was established in 1999 by the French Monitoring Centre for Drugs and Drug Addiction (OFDT) for monitoring the country's illicit synthetic drug market.⁶⁷ To accurately characterize the synthetic drugs available in the French market, SINTES compiles data from two sources: the law enforcement network, comprised of laboratories that analyze samples received from police and customs, and the field workers network, a diverse team of individuals that includes social workers, healthcare providers in needle exchange facilities, students, and volunteers in nightlife events.

While the information from the law enforcement component is added quarterly to the SINTES database in the form of analytical laboratory results, the registered and trained field workers reach out to people who use drugs directly to collect samples and anonymous questionnaires. These samples are sent to the laboratories of participating hospitals for analysis using gas chromatography and mass spectrometry. Results are then directly entered to the SINTES database.

It must be emphasized that the immediate purpose of SINTES is not to inform individual service users, but rather to maintain and expand a publically accessible surveillance database which can inform various prevention and harm reduction efforts and policies. As such, this drug checking facility does not involve a fixed consultation component; however, it is possible for an individual service user to ask for feedback regarding a submitted sample from a SINTES worker.

Combining data from drug seizures with drugs collected from users in various regions and settings has provided a relatively comprehensive overview of France's evolving synthetic drug market. Between 1999 and 2004, the system gathered 9,543 synthetic drug samples. In 2002 and 2003, the detection of unusual or dangerous substances in ecstasy tablets led to the release of public bulletins.

Mobile laboratories

Checkit! Drug checking service, Vienna

Mobile drug checking services for party settings was first established in Vienna in 1997.⁵ 'Checkit!' is a non-governmental organization with a mobile laboratory that can be transported to festivals and nightlife events. In addition to on-site drug checking, the staff provide service users with objective information about the risks associated with the substances submitted and offer brief counselling.⁶⁸

The service is divided into separate zones for sample preparation, analysis, and, information/counselling. Depending on the size of the event, the staff consists of up to seven chemists from the department of toxicology at the University Hospital of Vienna and up to 10 social workers and psychologists.⁶³ Due to legal restrictions, service users prepare their own samples using simple devices provided by staff in the sampling zone. The drug checking zone is equipped with four HPLC-MS systems that are used in parallel to test samples simultaneously. The results are posted next to the information and counselling zone within 15-30 minutes. Service users can identify their samples by the unique codes assigned to them.⁶⁰

The counselling and information services and the drug checking service can be accessed independently of each other so that the prospect of face-to-face communication is not perceived as a barrier to drug checking.⁶⁰ With this set up, the service analyses 100-120 samples and receives about 600 information/

counselling drop-ins per night.⁶⁰

Drug checking services in Zurich, Switzerland

In response to the increasing drug consumption among youth in the city of Zurich, Streetwork, a youth advisory facility, and Drug Information Centre (DIZ), an information and counselling centre, have provided mobile and stationary drug checking services since 2001 and 2006, respectively.³⁵ The Streetwork mobile service has been present in various party events in the city about 10 times per year. Service users submit the drug samples in person and fill out an anonymous questionnaire and receive face-to-face consultation and relevant information from a social worker while the test is conducted. The questionnaire is used to generate sociodemographic data concerning drug consumers who are not usually reflected in the existing statistics. The service users receive the drug analysis results within the session. Based on the success of Streetwork, DIZ has provided the same service in a fixed drug information and counselling centre since 2006. Both mobile and stationary facilities test drug samples using the HPLC technology on-site, and the results are communicated to the service user within the session, which typically lasts under 15 minutes.³⁵

The mobile laboratory was present at 84 events, and the stationary laboratory was open 172 days between 2001 and 2010. During this time, 7,622 consultations were completed, and 2,055 HPLC analyses were performed.³⁵ Though the questionnaires also yielded statistical information regarding opioid use among service users, the drugs analyzed by these services were predominantly 'party drugs' such as ecstasy, amphetamines, and cocaine. The number of people reached, samples analyzed, and consultation sessions lasting over 15 minutes have consistently increased annually since the inception of these services, and the data generated through the questionnaires and the drug analyses have facilitated a detailed understanding of Zurich's drug market, as well as the socioeconomic characteristics and consumption patterns of its consumers.³⁵

Conclusion

More research is needed to ascertain the effect of drug checking services on the drug use intentions and behaviours of service users, particularly people who use opioids regularly. However, the evidence currently available suggests that drug checking has been effective in monitoring the rapidly changing market of psychoactive drugs. This feature may be beneficial to people who use drugs regularly or occasionally.

Given the alarming influx of high potency and adulterated drugs in the market in British Columbia in recent years, and the corresponding increase in overdose deaths, real-time, consumer-derived, street level-generated data regarding trends in the illegal drug supply may be instrumental in appropriately allocating federal, provincial, and regional harm-reduction resources, and in providing potentially life-saving information to people who use illegal drugs.

Appendix A: Sample questionnaire for sample submission

This sample survey is translated from the website of Energy Control, Spain. It is produced below to provide a sense of the anonymous exchange of information between drug checking services and their patrons.

1. Sample nickname *

Give your sample a name so we can identify it (be original can you imagine how many “cocaine 1” we can analyze?). Remember to identify the sample with this pseudonym also in the envelope.

2. Contact *

E-mail or telephone so that we can send you the analysis information of the sample you send us.

3. User nickname *

This name will allow us to create a user in the system. It should always be the same even if different samples are sent

4. Age *

5. Sex *

- Female
- Male

6. Province where you got (purchased ...) the substance *

7. Approximate price (per gram or per unit) *

8. Indicate the date of acquisition of the substance you want to analyze *

9. Type of substance you want to send to analyze *

- | | |
|--|---|
| <input type="radio"/> MDMA in pill | <input type="radio"/> LSD |
| <input type="radio"/> MDMA powder or glass | <input type="radio"/> Heroin |
| <input type="radio"/> Cocaine | <input type="radio"/> 2CB or “Nexus” |
| <input type="radio"/> Speed | <input type="radio"/> Unknown (I’ve found it ...) |
| <input type="radio"/> Ketamine | <input type="radio"/> Other: <input type="text"/> |

10. Type of provider from whom you obtained this substance *

- Close person (ie. relative)
- "Dealer" (camel) of trust
- Unknown Dealer
- Populated
- At the party
- They brought it home
- Deep-web, Dark-net
- Self-cultivation
- Do not know, no answer
- Other:

11. Have you consumed part of the sample that you send us to analyze? *

(YES: If yes, continue the survey. NO: If no, now you only have to send the sample.)

- Yes
- No

12. How did you consume this substance?

- Orally
- Snorted
- Injected
- Smoked
- Other:

13. How much of this substance have you consumed?

(Note: If you have used pills, triplets, microdoses or drops, specify the amount you have taken (1/4, 1/2, 1 unit, 2 units ...) in the "other" section.)

- Less than one-quarter gram (<0.25 gram)
- Between a quarter gram and a half gram (0.25-0.50gr)
- Between half a gram and one gram (0.50 -1gr)
- More than one gram (> 1gr)
- Other:

14. Have you mixed with any other substance?

- Yes
- No

15. If yes, what substance(s) have you mixed with?

16. Mark the side effects that you felt after consuming the sample you send us.

(Select any that apply)

- Headache
- Insomnia
- Loss of appetite
- Tachycardia
- Nervousness
- Hallucinations
- Allergic reactions
- Fever
- Cough
- Sore throat
- Infection of the skin
- Other:

Appendix B. Advantages and Disadvantages of Drug Checking Technologies

Appendix B1. Colorimetric Reagent Tests

Advantages	Disadvantages
Low Cost	Limited accuracy
Speed	Limited range; only able to detect known compounds that are included in the reference swatches provided with the test kit
Portability	Lack of capacity for quantitative testing; little evidence of use on liquid or solid state samples
Ease of application	Little evidence of use for detecting fentanyl and other opioids
May be useful as preliminary analysis in tandem with other, more robust drug checking methods	Lack of consensus on whether it is beneficial to people who use drugs; false negative results may give an unwarranted sense of security

Appendix B2. Fourier-Transform Infrared Spectrometry (FTIR)

Advantages	Disadvantages
Portability	Does not identify unknown compounds
Speed	Not suitable for quantitative analysis on its own
High accuracy	
Ability to detect multiple compounds simultaneously	
No sample preparation or result interpretation required; testing requires minimal training	
Non-destructive testing; sample can be returned to client or used for further testing	

Appendix B3. Thin Layer Chromatography

Advantages	Disadvantages
Higher sensitivity compared to colorimetric testing	Much slower and less sensitive than the other separation-based technologies (i.e., HPLC and GC)
Cost-effective	May need to be used in conjunction with (gas chromatography-mass spectrometry) GC-MS to increase the accuracy of results
Requires little equipment; high potential for effective mobile drug checking applications in the Downtown Eastside or other areas	Not useful for detection of new drug adulterants; relies on a reference library of compounds.
Suitable for detection of known compounds	Not useful in situations where high volumes are expected (e.g., music festivals, the increase in samples around income assistance dispersion)

Appendix B4. High Performance Liquid Chromatography

Advantages	Disadvantages
(HPLC-MS) Highly adaptable for new psychoactive substances without significant modification	(Both HPLC-MS and HPLC-UV) Can only analyze one sample at a time; may not be feasible in situations involving a very large group of consumers seeking analysis in a short time period e.g., music festivals
(Both HPLC-MS and HPLC-UV) Able to quantify compounds, which is not possible with colorimetric testing	(Both HPLC-MS and HPLC-UV) Loading samples may be challenging if technicians are not allowed to handle the sample for legal reasons
(Both HPLC-MS and HPLC-UV) Very small amount of sample required for testing, minimizing the amount of drug a consumer must relinquish; may increase the likelihood of using this service	
(Both HPLC-MS and HPLC-UV) May be suitable for stationary settings such as a drop-off/mail-in sample service	
(Both HPLC-MS and HPLC-UV) May be a feasible method for mobile testing services	

Appendix B5. Gas Chromatography Mass Spectrometry

Advantages	Disadvantages
Amount of sample required for testing is quite small; may increase likelihood of consumers using this service	Sample preparation is generally more complicated and slower than HPLC-MS; not ideal for situations with high sample volume (e.g., music festivals)
	Selects for a smaller range of drugs compared to HPLC-MS; may not be suitable for developing a database on new drug adulterants

Appendix B6. Capillary electrophoresis

Advantages	Disadvantages
(CE-UV) Could be implemented in mobile, on-site, or drop-off/mail-in testing	(CE-UV) Unable to identify new compounds; not a viable method for developing a database on drug adulterants
(CE-UV) May be feasible in high volume situations where there are several machines available (e.g., music festivals) due to the speed, low amount of sample required for testing, and lower cost	(CE-MS) 10-100 times less sensitive than HPLC; potential to miss compounds present at low but clinically meaningful concentrations
(CE-MS) Able to identify new compounds	(Both) Has never before been used in drug checking; research and development may take more time and resources than with other methods
	(Both) Unforeseen barriers to implementation may arise

Appendix B7. Ion mobility spectrometry

Advantages	Disadvantages
Commercially available and cost-effective	Unable to definitively characterize a wide range of compounds as a standalone device
Easy to operate with minimal training	Prone to false positives as a standalone device
Can be miniaturized for portability	Has not been used for drug checking
Highly sensitive; able to detect trace amounts of target compounds with a small amount of sample	
Suitable for rapid screening due to high speed	
Can be couple with MS ad other separation-based devices for enhanced sensitivity and selectivity	

References

1. Drucker E, Anderson K, Haemmig R, et al. Treating Addictions: Harm Reduction in Clinical Care and Prevention. *Journal of bioethical inquiry*. 2016;13(2):239-249.
2. Harm Reduction International. What is Harm Reduction? <https://www.hri.global/what-is-harm-reduction>.
3. BC Coroners Service. Illicit Drug Overdose Deaths in BC January 1, 2007 – December 31, 2016. January 12017.
4. British Columbia Centre on Substance Use. A Guideline for the Clinical Management of Opioid Use Disorder. February 2017. Available from: http://www.bccsu.ca/wp-content/uploads/2017/02/BC-OD-Guidelines_FINAL.pdf.
5. Venture M, Noijen J, Bücheli A, Isvy A, van Huyck C, Martins D, et al. Drug checking service: good practice standards [Internet]. Nightlife Empowerment & Well-being Implementation Project (NEWIP); 2013. Available from: http://newip.safernightlife.org/pdfs/standards/NEWIP_D_standards-final_20.12-A4.pdf.
6. Brunt TM, Nagy C, Bucheli A, et al. Drug testing in Europe: monitoring results of the Trans European Drug Information (TEDI) project. *Drug testing and analysis*. 2017;9(2):188-198.
7. Tupper K, Mackenzie B. Street drug testing – Does Canada have a public health blind spot? Presentation at the Canadian Public Health Association Conference. Vancouver, BC. May 26, 2015.
8. Health Canada. Drug Analysis Services. Available from: : <http://www.hc-sc.gc.ca/hc-ps/substancontrol/analys-drugs-drogues/index-eng.php>.
9. Government of Canada. Joint Statement of Action to Address the Opioid Crisis. November 19, 2016. <https://www.canada.ca/en/health-canada/services/substance-abuse/opioid-conference/joint-statement-action-address-opioid-crisis.html>.
10. The Georgia Straight. Partiers Serious About Safe Fun. April 10, 2003. Available from: http://http://www.rave.ca/en/news_info/72236/all/
11. BC Ministry of Health. Harm Reduction: A British Columbia Community Guide. Victoria, BC. 2005. <http://www.health.gov.bc.ca/library/publications/year/2005/hrcommunityguide.pdf>
12. Michelow W, Dowden C. “Start small, take it easy”: results from the ANKORS harm reduction survey at the 2013 shambhala music festival [Internet]. Nelson, BC: ANKORS; 2015 [cited 2016 Nov 28]. Available from: <http://michelow.ca/doc/ankors-2013-smf-survey-report.pdf>.
13. Vancouver Coastal Health. 86% of drugs checked at Insite contain fentanyl. Vancouver, BC: Vancouver Coastal Health; 2016. Available from: <http://www.vch.ca/about-us/news/news-releases/86-of-drugs-checked-at-insite-contain-fentanyl>.
14. Wilson D. Victoria Pharmacy inds fentanyl in 90% of street drugs tested. CBC News. March 13, 2017. Available from: <http://www.cbc.ca/beta/news/canada/british-columbia/victoria-fentanyl-testing-pharmacy-uvic-1.4023011>.
15. Woo A. Pharmacy and professor team up to develop fentanyl-detection device. *The Globe and Mail*. March 15, 2017. Available from: <http://www.theglobeandmail.com/news/british-columbia/pharmacy-and-professor-team-up-to-develop-fentanyl-detection-device/article34317881/>.
16. Controlled Drugs and Substances Act, SC 1996, c 19. Available from: <http://laws-lois.justice.gc.ca/eng/acts/c-38.8/FullText.html>.
17. Sage C, Michelow W. Drug Checking at Music Festivals: A How-To Guide. Nelson, BC. 2016. Available from: <http://michelow.ca/doc/drug-checking-guide-online-v1.pdf>.
18. Ontario Agency for Health Protection and Promotion (Public Health Ontario), Leece P. Evidence Brief: Evidence on drug checking services as a harm reduction intervention. Toronto, ON: Queen’s Printer for Ontario; 2017.
19. Parliament of Canada. Bill-C_37: An Act to amend the Controlled Drugs and Substances Act and to make related Amendments to other Acts. Dec 12, 2016. Available from: <http://www.parl.gc.ca/HousePublications/Publication.aspx?Language=E&Mode=1&DocId=8695970>.
20. United Nations International Drug Control Programme Vienna. Rapid Testing Method of Drugs of Abuse Manual for Use by National Law Enforcement and Narcotics Laboratory Personnel [Internet]. New York, 1994. Available from: <https://www.unodc.org/pdf/publications/st-nar-13-rev1.pdf>.
21. United Nations Office on Drugs and Crime. Recommended Methods for the Identification and Analysis

- of Amphetamine, Methamphetamine and their Ring-Substituted Analogues in Seized Materials Manual for Use by National Drug Testing Laboratories. 2006. Available from: <https://www.unodc.org/pdf/scientific/stnar34.pdf>.
22. National Institute of Justice. Color Test Reagents/Kits for Preliminary Identification of Drugs of Abuse. 2000. Available from: <https://www.ncjrs.gov/pdffiles1/nij/183258.pdf>.
 23. Brunt TM, Niesink RJ. The Drug Information and Monitoring System (DIMS) in the Netherlands: implementation, results, and international comparison. *Drug testing and analysis*. 2011;3(9):621-634.
 24. Kriener H, Billeth R, Gollner C, Lachout S, Neubauer P. An inventory of on-site pill-testing interventions in the EU. Lisbon2001.
 25. Adamovics JA. Analysis of addictive and misused drugs. M. Dekker; 1995. 671 p.
 26. Anastos N, Barnett NW. Capillary electrophoresis for forensic drug analysis: A review. *Talanta*. 2005;67(2):269-279.
 27. Lurie IS, Hays PA, Garcia AE, Panicker S. Use of dynamically coated capillaries for the determination of heroin, basic impurities and adulterants with capillary electrophoresis. *Journal of chromatography. A*. 2004;1034(1-2):227-235.
 28. Rittgen J, Pütz M, Zimmermann R. Identification of fentanyl derivatives at trace levels with nonaqueous capillary electrophoresis-electrospray-tandem mass spectrometry (MSn, n = 2, 3): Analytical method and forensic applications. *ELECTROPHORESIS*. 2012;33(11):1595-1605.
 29. United Nations International Drug Control P. Recommended Methods for Testing Opium, Morphine and Heroin. Vienna1998.
 30. Allemann D, Pauli H, Murner A, Helmlin H-J, Steiner S. Poster: Substance Testing on the Dance Floor with a Mobile High-tech Lab. 2010.
 31. Hungerbuehler I, Buecheli A, Schaub M. Drug Checking: A prevention measure for a heterogeneous group with high consumption frequency and polydrug use - evaluation of Zurich's drug checking services. *Harm Reduction Journal*. 2011;8:16.
 32. Barbarin N, Henion JD, Wu Y. Comparison between liquid chromatography-UV detection and liquid chromatography-mass spectrometry for the characterization of impurities and/or degradants present in trimethoprim tablets. *Journal of chromatography. A*. 2002;970(1-2):141-154.
 33. Toske SG, Cooper SD, Morello DR, Hays PA, Casale JF, Casale E. Neutral Heroin Impurities from Tetrahydrobenzylisoquinoline Alkaloids. *Journal of Forensic Sciences*. 2006;51(2):308-320.
 34. Wu AH, Gerona R, Armenian P, French D, Petrie M, Lynch KL. Role of liquid chromatography-high-resolution mass spectrometry (LC-HR/MS) in clinical toxicology. *Clinical Toxicology*. 2012;50(8):733-742.
 35. Sabino BD, Romão W, Sodr e ML, et al. Analysis of Cocaine and Crack Cocaine via Thin Layer Chromatography Coupled to Easy Ambient Sonic-Spray Ionization Mass Spectrometry. *American Journal of Analytical Chemistry*. 2011;2(6):658-664.
 36. Morello DR, Meyers RP. Qualitative and Quantitative Determination of Residual Solvents in Illicit Cocaine HCl and Heroin HCl. *Journal of Forensic Sciences*. 1995;40(6):13863J-13863J.
 37. Forbes TP, Najarro M. Ion mobility spectrometry nuisance alarm threshold analysis for illicit narcotics based on environmental background and a ROC-curve approach. *The Analyst*. 2016;141(14):4438-4446.
 38. Chouinard CD, Wei MS, Beekman CR, Kemperman RH, Yost RA. Ion Mobility in Clinical Analysis: Current Progress and Future Perspectives. *Clin Chem*. 2016;62(1):124-133.
 39. Liuni P, Romanov V, Binette MJ, et al. Unambiguous characterization of analytical markers in complex, seized opiate samples using an enhanced ion mobility trace detector-mass spectrometer. *Anal Chem*. 2014;86(21):10772-10779.
 40. Armenta S, Garrigues S, de la Guardia M, et al. Detection and characterization of emerging psychoactive substances by ion mobility spectrometry. *Drug Testing and Analysis*. 2015;7(4):280-289.
 41. Gwak S, Almirall JR. Rapid screening of 35 new psychoactive substances by ion mobility spectrometry (IMS) and direct analysis in real time (DART) coupled to quadrupole time-of-flight mass spectrometry (QTOF-MS). *Drug testing and analysis*. 2015;7(10):884-893.
 42. Verkouteren JR, Staymates JL. Reliability of ion mobility spectrometry for qualitative analysis of complex, multicomponent illicit drug samples. *Forensic science international*. 2011;206(1-3):190-196.
 43. Camilleri AM, Caldicott D. Underground pill testing, down under. *Forensic science international*. 2005;151(1):53-58.
 44. Elkins KM, Weghorst AC, Quinn AA, Acharya S. Colour quantitation for chemical spot tests for a controlled substances presumptive test database. *Drug testing and analysis*. 2017;9(2):306-310.

45. Winstock AR, Wolff K, Ramsey J. Ecstasy pill testing: harm minimization gone too far? *Addiction* (Abingdon, England). 2001;96(8):1139-1148.
46. Jarvie DR, Simpson D. Drug screening: evaluation of the Toxi-Lab TLC system. *Annals of clinical biochemistry*. 1986;23 (Pt 1):76-84.
47. Lurie IS, Driscoll SE, Cathapermal SS, Panicker S. Determination of heroin and basic impurities for drug profiling by ultra-high-pressure liquid chromatography. *Forensic science international*. 2013;231(1-3):300-305.
48. United Nations Office on D, Crime. *Methods for Impurity Profiling of Heroin and Cocain*. New York 2005.
49. Bull ID. *High Performance Liquid Chromatography Mass Spectrometry (HPLC/MS)*. 2005.
50. Smith ML, Vorce SP, Holler JM, et al. Modern instrumental methods in forensic toxicology. *Journal of analytical toxicology*. 2007;31(5):237-253, 238A-239A.
51. Kline ND, Tripathi A, Mirsafavi R, et al. Optimization of Surface-Enhanced Raman Spectroscopy Conditions for Implementation into a Microfluidic Device for Drug Detection. *Analytical chemistry*. 2016;88(21):10513-10522.
52. Weyermann C, Mimoune Y, Anglada F, Massonnet G, Esseiva P, Buzzini P. Applications of a transportable Raman spectrometer for the in situ detection of controlled substances at border controls. *Forensic Science International*. 2011;209 (1-3):21-28.
53. Dana K, Shende C, Huang H, Farquharson S. Rapid Analysis of Cocaine in Saliva by Surface-Enhanced Raman Spectroscopy. *J Anal Bioanal Tech*. 2015;6(6):1-5.
54. Schütz H, Paine A, Erdmann F, Weiler G, Verhoff MA. Immunoassays for drug screening in urine. *Forensic Science, Medicine, and Pathology*. 2006;2(2):75-83.
55. Tregoning W. *Drug Checking Services: Brief*. Unharm. May 2016. Available at: https://d3n8a8pro7vhmx.cloudfront.net/unharm/pages/114/attachments/original/1463543813/Drug_checking_brief_Will_Tregoning_for_Unharm_2016.pdf?1463543813.
56. Ritter A, Cameron J. A review of the efficacy and effectiveness of harm reduction strategies for alcohol, tobacco and illicit drugs. *Drug Alcohol Rev*. 2006;25(6):611-624.
57. Benschop A, Rabes M, Korf DJ. *Pill testing, ecstasy & prevention : a scientific evaluation in three European cities*. Amsterdam: Rozenberg; 2002.
58. Kriener H, Schmid R. Check your pills. Check your life. ChEck it!! High quality on-site testing of illicit substances. Information counselling and safer use measures at raves in Austria [Internet]. Vienna: CheckIT!. 2002. Available from: <http://web.archive.org/web/20081021045950/http://www.drugtext.org/library/articles/kriener.htm>.
59. Kerr T, Small W, Hyshka E, Maher L, Shannon K. 'It's more about the heroin': injection drug users' response to an overdose warning campaign in a Canadian setting. *Addiction* (Abingdon, England). 2013;108(7):1270-1276.
60. British Broadcasting Corporation. *UK Calls to Ban Ecstasy Testing Kit*. May 27, 1998. Available from: http://news.bbc.co.uk/2/hi/uk_news/101369.stm.
61. Brunt TM, Rigter S, Hoek J, Vogels N, van Dijk P, Niesink RJ. An analysis of cocaine powder in the Netherlands: content and health hazards due to adulterants. *Addiction* (Abingdon, England). 2009;104(5):798-805.
62. Giraudon I, Bello PY. Monitoring ecstasy content in France: results from the National Surveillance System 1999-2004. *Subst Use Misuse*. 2007;42(10):1567-1578.
63. Schmid R. *Drug testing at music events - A low threshold drug prevention program for young consumers of synthetic drugs*. Medical University of Vienna, Austria, 2013. Available at: <http://www.ewdts.org/data/uploads/vienna/ewdts2013-schmid.pdf>.