

The analysis of amphetamine-type stimulants using microchip capillary electrophoresis

Aimee Lloyd



A thesis submitted for the

Degree of Doctor of Philosophy (Science)

University of Technology, Sydney

July, 2013

Simplicity is the ultimate sophistication

Leonardo da Vinci

Certificate of authorship and originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged in the text.

I also certify that the thesis has been written by me. Any help I received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all the information sources and literature used are indicated in the thesis.

Aimee Lloyd

31st July 2013

Acknowledgements

Many people have supported and guided me throughout this mammoth project. It has been an incredible journey and I would like to thank each and every one of you. The insightful discussions, constructive advice and feedback has greatly influenced my personal and intellectual development and opened my mind to new ideas. I am grateful for the funding sources that allowed me carry out this research and attend various meetings and conferences.

To my supervisors, Claude Roux and Philip Doble, thank you for your invaluable advice, patience and support throughout my thesis. I am indebted to you both for giving me the chance to embark on such an exciting research project and for the unique opportunities along the way. Claude, my sincere appreciations go to you for your understanding and ongoing support despite your many other commitments. You always believed in me and encouraged me to shape my own interests and ideas, not only with my project but in Forensic Science. Philip, the insightful advice and discussions you imparted on me have enabled me to grow intellectually. Thank you for persuading me to pursue a PhD and guiding me through my research.

A big thank you to Lucas, my mentor, for motivating me throughout my postgraduate studies; you inspired me to develop as a researcher. I admire your positive outlook and ability to smile despite the situation. As an honorary supervisor, you were always keen to lend a hand - even extending your expert technical services all the way to NZ.

To the illicit drug and clan lab teams of ESR, in particular Matthew Russell, I am really appreciative of the invaluable opportunity to research in collaboration with you. Matt, thank you for your generous support; I have greatly benefited from your interest and commitment to my field work studies.

To Pierre Esseiva, Pierre Margot, Oliver Ribaux and colleagues of the University of Lausanne, I am forever indebted to you all for the opportunity to grow and gain insight into Forensic Science in Switzerland. Thank you to the Australian Government

for awarding me with an Endeavour Postgraduate Award to make this exchange possible and to Agilent Technologies for providing and transporting the equipment.

To my fellow postgraduate students and support staff of whom I had the pleasure of working with. Thank you for providing such a positive and enjoyable research environment; I will always have great memories from our excursions to conferences and beyond. A special thanks to Marie for being such a caring and dependable friend – our morning coffees, mixed with advice and suggestions, got me through the tough times.

To my loving boyfriend Nic, thank you for believing in me and keeping me positive – especially during the latter stages. You inspired me to get over the final hurdles and always took time to cheer me up. Thank you for your patience and the hours you spent proof-reading drafts of my thesis.

Last but not least, to my Mum, Dad and sister Hannah: you have always supported, encouraged and believed in me in all my endeavours. Your guidance and persistent help has enabled me to realise my full potential. This thesis would not have been possible without your unconditional love and support.

Table of contents

Certificate of authorship and originality.....	iii
Acknowledgements.....	iv
Table of contents.....	vvi
List of figures.....	xii
List of tables.....	xviii
Abbreviations.....	xxix
Abstract.....	xxiv
List of publications and presentations	xxv
Chapter 1:	
Introduction.....	2
1.1 Amphetamine-type stimulants (ATS)	3
1.1.1.1 Classification.....	3
1.1.1.1 Terminology.....	7
1.1.2 History	8
1.1.2.1 Amphetamines.....	9
1.1.2.2 3,4-Methylenedioxymethamphetamine (MDMA)	12
1.1.3 Recent trends in Australasia	12
1.1.4 Physiological and behavioral effects.....	16
1.1.4.1 Amphetamines.....	17

1.1.4.2	MDMA and analogues	18
1.1.4.3	Cathinones	19
1.1.5	Legislation	19
1.1.5.1	International framework	19
1.1.5.2	Australasian framework.....	21
1.1.6	Manufacture.....	24
1.1.6.1	Synthetic routes.....	26
1.1.6.2	Methamphetamine.....	26
1.1.6.3	Amphetamine	30
1.1.6.4	MDMA and analogues	31
1.1.6.5	Cathinones	32
1.1.6.6	Summary.....	33
1.1.7	Analysis.....	34
1.1.7.1	Screening	39
1.1.7.2	Identification.....	42
1.1.7.3	Emerging techniques	44
1.2	Microchip capillary electrophoresis (MCE)	49
1.2.1	Principles of capillary electrophoresis	50
1.2.1.1	Instrumentation.....	50
1.2.1.2	Electroosmotic flow	52
1.2.1.3	Injection.....	53

1.2.1.4	Separation modes.....	54
1.2.1.5	Detection	56
1.2.1.6	Influencing factors	58
1.2.2	Microchip design and function.....	60
1.2.2.1	Introduction	60
1.2.2.2	Microchip design	62
1.2.2.3	Injection	63
1.2.2.4	Separation.....	65
1.2.2.5	Detection modes	65
1.2.2.6	Influencing factors	69
1.2.3	Forensic applications.....	69
1.2.4	Agilent Bioanalyzer.....	72
1.2.4.1	Chip design.....	73
1.2.4.2	Sample movement.....	74
1.2.4.3	Detection	77
1.3	Aims of research.....	79

Chapter 2:

	Optimisation of the analysis of ATS using the Bioanalyzer.....	82
2.1	Introduction.....	82
2.2	Materials and methods	85
2.2.1	Apparatus	85

2.2.2	Chemicals	85
2.2.3	Electrolyte preparation	85
2.1.3	Analyte preparation	86
2.1.3.1	FITC stock solution	86
2.1.3.2	Amphetamine analogues and ATS standards	86
2.3	Results and discussion	87
2.3.1	Labelling with FITC	87
2.3.2	Electrolyte optimisation	90
2.3.3	Instrumental parameters	91
2.3.4	Microchip cleaning procedure	91
2.3.5	Separation of labelled analogues and ATS	92
2.4	Conclusions	95
 Chapter 3:		
Screening of methamphetamine, ephedrine and pseudoephedrine in samples from clandestine laboratories		
3.1	Introduction	97
3.2	Materials and methods	99
3.2.1	Lab-on-a-chip apparatus	99
3.2.2	Chemicals	99
3.2.3	Electrolyte preparation	100
3.2.4	Preparation of stock solutions for analytical samples	100

3.2.5	Sample preparation methods	101
3.2.5.1	Pharmaceutical preparations containing pseudoephedrine	101
3.2.5.2	Clandestine laboratory samples	101
3.2.5.3	Simulated alcohol wipes	104
3.2.6	Fluorescent derivatisation procedure	104
3.3	Results and discussion	104
3.3.1	Preparation of samples	104
3.3.2	Migration time variation of the standard mixture	105
3.3.3	Analysis of clandestine laboratory samples	106
3.3.3.1	Part I: Pharmaceutical preparations containing pseudoephedrine	106
3.3.3.2	Part II: Clandestine laboratory liquids	108
3.3.3.3	Part III: Simulated surface swabs	112
3.3.4	In-field applications	114
3.4	Conclusions	115
 Chapter 4:		
	Screening and comparative analysis of synthetic cathinone seizures	117
4.1	Introduction	117
4.2	Materials and methods	120
4.2.1	Apparatus	120
4.2.2	Chemicals and reagents	120

4.2.3	Electrolyte preparation	120
4.2.4	Sample preparation.....	120
4.2.5	Fluorescent derivatisation procedure.....	121
4.3	Results and discussion.....	122
4.3.1	Derivatisation procedure	122
4.3.2	Separation of visually different tablets.....	124
4.3.3	Reproducibility of tablet profiles	126
4.3.4	Current methods	128
4.3.5	Applications of MCE as a comparison tool.....	129
4.3.5.1	Scenario 1.....	130
4.3.5.2	Scenario 2.....	132
4.3.6	Further enhancements for routine use.....	133
4.4	Conclusions.....	134
 Chapter 5:		
	Concluding remarks and future work.....	136
	References	142

List of figures

Figure 1.1	Structure of β -PEA.	4
Figure 1.2	Possible substitution positions R1-R9. Adapted from ¹³	4
Figure 1.3	Molecular structure of amphetamine.	5
Figure 1.4	Molecular structure of methamphetamine.	5
Figure 1.5	Molecular structure of MDMA.	6
Figure 1.6	The generic structure of synthetic cathinones, showing α and β side-chain positions.	7
Figure 1.7	Benzedrine tablets in an early medical journal advertisement. ³⁹	10
Figure 1.8	Number of clandestine laboratories detected in Australasia from 1997 to 2006. ^{6,57,58}	13
Figure 1.9	ATS seized worldwide, by weight, 2002-2010. ⁷	14
Figure 1.10	New psychoactive substances notified to the European early-warning system from 2005 to 2011. ⁶⁵	16
Figure 1.11	The predominant synthetic routes employed in the illicit manufacture of amphetamines. To synthesise amphetamine: ^a use norpseudoephedrine or norephedrine; to synthesise methamphetamine ^b use Al and HgCl ₂ in the place of ammonia, ^c use N-methylformamide in the place of formamide. Adapted from ¹¹²	28
Figure 1.12	Synthetic pathways involved in the manufacture of 3,4-MDP-2-P from piperonal, safrole and isosafrole. * Intermediate products formed. To	

	subsequently reduce 3,4-MDP-2-P to MDMA the: (1) Leuckart reaction and (2) reductive amination routes can be used. Adapted from ^{111,112}	32
Figure 1.13	Preparation of methcathinone from ephedrine/pseudoephedrine. Adapted from ¹²⁷	33
Figure 1.14	Preparation of racemic methcathinone from propiophenone. Adapted from ¹²⁷	33
Figure 1.15	Flowchart illustrating the analysis scheme followed for the examination of drug seizures: ^a Sorting is based on visual similarity, ^b the procedure followed for identifying a liquid and processing liquids from clandestine laboratories is discussed further in chapter 3, ^c screen is performed if sample permits. Trace is defined as a sample that is barely visible to the naked eye, whilst bulk can be defined as more than 10 units or a surplus of one unit (≤ 10 kg). Adapted from ¹⁶	36
Figure 1.16	The instrumental set-up of a CE system. V_{inj} is the applied voltage. Adapted from ¹⁸³	51
Figure 1.17	Schematic representation of the interface between a glass surface and an aqueous solution. ¹⁸⁵	52
Figure 1.18	Sodium dodecyl sulphate; Left: monomer, Right: micelle.	55
Figure 1.19	Micellar electrokinetic chromatography using an anionic surfactant beyond the CMC (normal polarity mode).	56
Figure 1.20	Three dimensional representation of a planar microfluidic chip. A-A = cross section of microchip. Adapted from ²⁰¹	62
Figure 1.21	Cross-channel microchip designs. Left: orthogonal, Right: t-cross channel. Reservoirs refer to: S = sample, B = buffer, SW = sample waste	

	and BW = buffer waste. An electrode is situated at each reservoir and connected to a high voltage power supply.	63
Figure 1.22	Gated and pinched injection modes. S = sample, B = buffer, SW = sample waste and BW = buffer waste. The dotted line represents BGE flow and the solid line represents sample flow. Adapted from ²⁰¹	64
Figure 1.23	Schematic of the general set-up of an amperometric detection cell for LOC applications. ²⁰⁹	66
Figure 1.24	Basic elements of a fluorescence detection system. Adapted from ¹⁸⁴	68
Figure 1.25	Agilent Bioanalyzer 2100. ²³⁷	72
Figure 1.26	Bioanalyzer platform illustrating the point of contact between the microchip and the electrode cartridge. ²³⁸	73
Figure 1.27	Microchip fabrication procedure. ²⁴⁰	73
Figure 1.28	Chip design. Left: Microchip (Caliper). Right: schematic of the microchip design (actual size 17 mm square). ²³⁷	74
Figure 1.29	The steps involved in sample injection, separation and detection (not to scale). Adapted from ²⁴¹	76
Figure 1.30	The optics configuration of the LED-IF detector in the Agilent Bioanalyzer 2100. The LED alignment and collection of the fluorescent signal is illustrated. ²⁴⁴	77
Figure 1.31	Excitation and emission spectra of FITC. ²⁴⁷	78
Figure 1.32	Thiocarbamylation reaction of FITC with amphetamine-type stimulants.	79

- Figure 2.1 Sample preparation and analysis workflow. Left to right: exhibit or standard, sample vial containing FITC, dry heating block, Agilent DNA chip, Agilent 2100 Bioanalyzer platform. 86
- Figure 2.2 The influence of temperature on the fluorescence intensity of derivatised PSE (5 minute reaction time). Error bars represent the corresponding standard deviations of the peak heights for each temperature experiment (n = 3), and triplicate injection of derivatised PSE. Each experiment was performed on a separate chip..... 88
- Figure 2.3 The influence of time on the fluorescence intensity of derivatised PSE for a reaction performed at 90 °C. Error bars represent the corresponding standard deviations of the derivatisation time periods for each temperature experiment (n = 3), and triplicate injection of derivatised PSE. Each experiment was performed on a separate chip. 89
- Figure 2.4 Separation profiles of the fluorescence intensity for amphetamine (a) 24 hours at room temperature, (b) 3 minute microwave program – 30 second periods alternating between microwave application and resting, (c) 3 minutes at 90 °C. Separation conditions as in Figure 2.5. (1) 2-MMA, (2) 2-4-MPEA, (3) MPEA, (4) AM-C-BD, (5) BMBA. 90
- Figure 2.5 Electropherogram of 5 amphetamine analogues (5 µg/mL) using LED-IF (λ_{em} 470, λ_{em} 525). Conditions: 50 mM SDS + 50 mM sodium tetraborate, pH 9.66; 25°C; injection time 2 seconds; injection voltage 1.5 kV; separation voltage 1.5 kV; (1) 2-MMA, (2) 2-4-MPEA, (3) MPEA, (4) AM-C-BD, (5) BMBA. 92
- Figure 2.6 Electropherogram showing the optimised separation of 3 ATS standards (5 µg/mL) using LED-IF (λ_{em} 470, λ_{em} 525). Conditions: 50 mM SDS + 50 mM sodium tetraborate, pH 9.66; 25°C; injection time 2 seconds; injection voltage 1.5 kV; separation voltage 1.5 kV; (1) PSE, (2) AMP, (3) MA. 93

Figure 3.1	Left: Simplified outline of methamphetamine manufacture employing the HI reduction method; Right: samples resulting from each step.....	98
Figure 3.2	The clandestine laboratory processing sequence to determine which sample preparation method to follow. *These samples were two-layered liquids at the scene.....	102
Figure 3.3	Separation of a standard mixture of ephedrine, pseudoephedrine and methamphetamine.....	105
Figure 3.4	Fluorescent responses from LOC analyses of (a) the solvent layer of two-layered liquid sample 3, (b) acidic liquid 3. Numbers correspond to the results presented in Table 3.5.....	111
Figure 4.1	The structures of target analogues often present in MEC tablets. 4-MEC = 4-methylethcathinone, 4-MMC = 4-methylmethcathinone, NEA = N-ethylamphetamine, NEC = N-ethylcathinone, bk-MBDB = β -keto-3,4-methylbenzodioxylbutamine, bk-MDMA = β -keto-3,4-methylenedioxyamphetamine and MDPBP = 3',4'-methylenedioxy- α -pyrrolidinobutiophenone. * NEA, a derivative of amphetamine, is not part of the synthetic cathinone family.	122
Figure 4.2	Generic ATS derivative chemical structure.	122
Figure 4.3	Comparison between MCE electropherograms for (a) FITC blank, (b) 4-MEC and (c) MDPBP.	124
Figure 4.4	Comparison between the MCE profiles of four visually different MEC tablets found to contain different mixtures of synthetic cathinones.	125
Figure 4.5	MCE separation profiles obtained for 3 tablets from the same seizure with corresponding tablet photos.....	131

Figure 4.6 Summary of the MCE analyses of 5 visually similar tablets from the same seizure (a) MCE profiles (b) Analytical data (c) Photo of the tablets analysed, showing their visual similarities.....133

List of tables

Table 1.1	Summary of the behavioural effects, development of tolerance and effects of prolonged use for amphetamines and MDMA-related stimulants. ⁷⁰	17
Table 1.2	ATS scheduled in the <i>1971 Convention on Psychotropic Substances</i> as of May 2010. Adapted from. ⁸⁰	20
Table 1.3	ATS pre-cursors scheduled in the <i>1988 Convention against Illicit Traffic in Narcotic and Psychotropic Substances</i> as of January 2012. Adapted from. ⁸⁶	21
Table 1.4	Controlled ATS quantities and associated maximum penalties under the Criminal Code Act 1995. ⁹²	22
Table 1.5	Thresholds for trafficable quantities of amphetamine, methamphetamine and MDMA, by drug type and jurisdiction. ⁹⁶ * Based on pure drug (excluding inert material).	23
Table 1.6	Summary of the predominant synthetic routes of clandestine ATS manufacture.	34
Table 1.7	Categories of analytical techniques from SWGDRUG recommendations. *Examples of pharmaceutical identifiers include physical characteristics of tablets, capsules or packaging indicating the identity, manufacturer or quantity of the substances present. ¹³⁰	39
Table 1.8	Colour test results observed with common reagents for ATS and their pre-cursors. Adapted from ¹³	41
Table 1.9	The advantages and disadvantages of some commonly employed for the conclusive identification of seized drugs. Adapted from ¹⁴	44

Table 1.10	A summary of some commercially available portable drug analysis devices. * Although commercially available, lab-on-a-chip is not marketed for drug screening. This technique is presented as an alternative to existing commercial techniques.....	46
Table 1.11	Summary of MCE analysis of ATS. AMP = amphetamine, METH = methamphetamine, EPH = ephedrine, PSE = pseudoephedrine, nor-EPH = nor-ephedrine, nor-PSE = nor-pseudoephedrine, CAT = cathinone, MCAT = methcathinone, DA = doxylamine, OA = octopamine, NA = noradrenaline, A = adrenaline, IP = isoproterenol.	71
Table 2.1	Structures of the target amphetamines and amphetamine analogues.	84
Table 2.2	Analytical performance data for amphetamine analogues and ATS. ^a LOD and LOQ calculations were determined using 3 times and 10 times the signal-to-noise ratio, respectively (n = 6).....	94
Table 2.3	Separation and detection reproducibility for amphetamine analogues and ATS. ^a Calculated from repeat injections of a 30 mg/mL standard mixture..	95
Table 3.1	Sample preparation procedures followed for each clandestine laboratory sample. * basify to pH 14 **adjust to pH 8-10, if required, prior to derivatisation.....	103
Table 3.2	Data for the analysis of pseudoephedrine in 5 cold & flu liquids, reported concentrations were determined from the label on each bottle. * Analysed in duplicate.....	107
Table 3.3	Data for the analysis of pseudoephedrine in 5 gel capsules. Concentrations were taken from the packaging of each gel capsule, w/w = average weight of pseudoephedrine present in each capsule. * Analysed in duplicate.	107

Table 3.4	Migration time and peak area data for the analysis of pseudoephedrine in 10 pharmaceutical tablets for two aliquots. Concentrations of pseudoephedrine and paracetamol are reported for 3 mg/mL solutions of each tablet. Peak areas were normalised to a pseudoephedrine standard of 1 mg/mL.	108
Table 3.5	Summary of the results obtained for clandestine laboratory samples using LOC with a comparison to GC-MS. NEG = no result, PSE/EPH – Either or both pseudoephedrine and ephedrine (i.e. – not confirmed by further analysis). * Two-layered liquid, both layers pH 6 therefore both layers analysed. TL = top layer, BL = bottom layer.....	110
Table 3.6	Migration time data for the extraction of methamphetamine from different household surfaces. * Samples analysed in duplicate.	113
Table 4.1	Structural classification of the target stimulants. Refer to the ATS derivative structure presented in Figure 4.2.....	123
Table 4.2	Summary of the migration time and peak height data for 10 tablets.	127
Table 4.3	Summary of analytical data obtained for 3 visually different tablets from one seizure.....	131

Abbreviations

AFP	Australian Federal Police
AIC	Australian Institute of Criminology
AMP	amphetamine
ATR-FTIR	attenuated total reflection – fourier transform infrared
ATS	amphetamine-type stimulants
CE	capillary electrophoresis
CMC	critical micellar concentration
CNS	central nervous system
CZE	capillary zone electrophoresis
DNA	deoxyribonucleic acid
DTAF	5-([4,6-dichlorotriazin-2-yl]amino)fluorescein
ED	electrochemical detection
EMCDDA	European Monitoring Centre for Drugs and Drug Addiction
EOF	electroosmotic flow
ESI	electrospray ionisation
ESR	institute of environmental science and research limited
FITC	fluorescein isothiocyanate isomer I

FTIR	fourier transform infrared
GC	gas chromatography
HPLC	high performance liquid chromatography
Hypo	hypophosphorus
IMS	ion mobility spectrometry
LC-MS	liquid chromatography-mass spectrometry
LED	light-emitting diode
LIF	laser-induced fluorescence
LOC	lab-on-a-chip
LOD	limit of detection
LOQ	limit of quantification
MA	methamphetamine
MCE	microchip capillary electrophoresis
MDA	3,4-methylenedioxyamphetamine
MDEA	3,4-methylenedioxyethylamphetamine
MDMA	3,4-methylenedioxymethamphetamine
3,4-MDP-2-P	3,4-methylenedioxyphenyl-2-propanone
MDPBP	3',4'-methylenedioxy- α -pyrrolidinobutiophenone

4-MEC	4-methylethcathinone
MEKC	micellar electrokinetic chromatography
4-MMC	4-methylmethcathinone
MS	mass spectra
MS	mass spectrometry
NFSTC	National Forensic Science Technology Centre
NIR	near infra-red
OPA	o-phthalaldehyde
P2P	phenyl-2-propanone
PSE	pseudoephedrine
RSD	relative standard deviation
SDS	sodium dodecyl sulfate
SWGDRUG	scientific working group for the analysis of seized drugs
μ -TAS	μ -total analytical systems
TLC	thin layer chromatography
UN	United Nations
UNODC	United Nations Office on Drugs and Crime
β -PEA	β -phenethylamine

Abstract

The illicit drug trade, dominated by sophisticated trans-national criminal organisations, has put increasing demands on law enforcement bodies. Timely information concerning illegal activity is required to effectively combat the illicit drug problem. Rapid, if not real-time, identification tools would help direct investigators with sampling procedures and safety precaution measures at drug-related crime scenes. In addition to enhancing work-flow processes, for example the creation of *rapid laboratories* or intelligence units, a major focus rests on the miniaturisation of existing analytical techniques, predominantly spectroscopic-based, in order to create field portable tools for this purpose. Currently available techniques such as colour tests, Raman and infra-red spectrometers often have limitations associated with specificity, portability and sample preparation requirements. The diverse nature of exhibits present challenges for the in-field detection of controlled drugs and precursors.

An emerging area of research, lab-on-a-chip (LOC), with its ability to integrate multiple functions on a microchip, has shown promising applications for in-field testing. The aim of this project was to evaluate a commercial portable microchip capillary electrophoresis (MCE) platform, the Agilent Bioanalyzer 2100, for the analysis of amphetamine-type stimulants (ATS). This device, although designed for the analysis of biological molecules, holds significant potential for the analysis of inorganic ions, explosives and illicit drugs. This project focused on developing and optimising a rapid, simple and inexpensive separation method. The method was adapted for the analysis of a wide range of casework exhibits including liquids, tablets and powders in order to test its in-field capabilities. The prospects, challenges and applications are discussed. This research has highlighted MCE as a competitive platform for the screening of ATS and has demonstrated its potential use in forensic drug analysis.

List of publications and presentations

Lloyd, A., Russell, M., Blanes, L., Doble, P. and Roux, C. Lab-on-a-chip screening of methamphetamine and pseudoephedrine in samples from clandestine laboratories. *Forensic Science International*. 2013; 228(1-3): 8-14.

Lloyd, A., Blanes, L., Beavis, A., Roux, C. and Doble, P. A rapid method for the in-field analysis of amphetamines employing the Agilent Bioanalyzer. *Analytical Methods*. 2011; 3(7): 1535-1539.

Lloyd, A., Russell, M., Somerville, R., Doble, P. and Roux, C. The use of portable microchip electrophoresis for the screening and comparative analysis of synthetic cathinone seizures. Submitted to *Forensic Science International (manuscript ID: FSI-S-13-01367)*.

Lloyd, A., Russell, M., Blanes, L., Doble, P. and Roux, C. Rapid screening for pseudoephedrine and methamphetamine in clandestine laboratory samples using the Agilent 2100 Bioanalyzer [oral presentation]. 2012; *The 21st International Symposium on the Forensic Sciences of the Australian and New Zealand Forensic Science Society (ANZFSS) Hobart, Tasmania, Australia*.

Lloyd, A., Doble, P., Roux, C., Esseiva, P. and Delémont, O. Comparison between microchip capillary electrophoresis and capillary electrophoresis-mass spectrometry for the detection of amphetamines [oral presentation]. 2011; *19th International Association of Forensic Sciences (IAFS) world meeting, Funchal, Madeira, Portugal*.

Lloyd, A., Blanes, L., Beavis, A., Roux, C. and Doble, P. Analysis of amphetamine analogues using the portable Bioanalyzer 2100 lab-on-a-chip [poster presentation]. 2010; *17th International Symposium on Capillary electroseparation techniques (ITP 2010), Baltimore, Maryland, United States*.

Lloyd, A., Blanes, L., Beavis, A., Roux, C. and Doble, P. Analysis of amphetamine-type stimulants using the portable Bioanalyzer 2100 lab-on-a-chip [poster presentation].

2010; *The 20th International Symposium on the Forensic Sciences of the Australian and New Zealand Forensic Science Society (ANZFSS), Sydney, NSW, Australia.*