A Public Health Perspective on the Recovery and Remediation of Methamphetamine Contaminated Surfaces

By

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LIST OF ABBREVIATIONS

ACIC	Australian Criminal Intelligence Commission
ATS	Amphetamine-Type Stimulants
EHA	Environmental Health Australia
EHO	Environmental Health Officer
HPLC	High Performance Liquid Chromatography
Ice	Crystalline methamphetamine
IICRC	Institute of Inspection Cleaning and Restoration Certificate
LC-MS/MS	Liquid Chromatography with tandem Mass Spectrometry
LCMS	Liquid Chromatography Mass Spectrometry
LOAEL	Lowest Observed Adverse Effect Level
MDA	3,4-methylenedioxyamphetamine
MDMA	3,4-methylenedioxymethamphetamine
METH	Methamphetamine
MR	Methamphetamine Remediation
NATA	National Association for Testing Authorities
NEHA	National Environmental Health Association
NIOSH	National Institute for Occupational Safety & Health
NOAEL	No Observed Adverse Effect Level
NZ	New Zealand
NZS	New Zealand Standard (NZS8510:2017)
PhD	Doctor of Philosophy

SBS	Sick Building Syndrome
THEM	Thirdhand Exposure to Methamphetamine
UHPLC	Ultra High Performance Liquid Chromatography
UNODC	United Nations Office on Drugs and Crime
UK	United Kingdom
US	United States
USA	United States of America
VOC	Volatile Organic Compounds
WHO	World Health Organization

ABSTRACT

Methamphetamine is an illicit drug that is ingested, injected, or inhaled, and can be manufactured in clandestine laboratories. Vapours from the manufacture and smoking processes generate residues that are absorbed by porous and non-porous surfaces, such as walls, furniture and soft furnishings. Exposure to methamphetamine can cause adverse health effects in those residing within a contaminated property. The next step is to contact a testing and decontamination company to assess the level of contamination and remediate it.

The overall aim of this thesis was to investigate the public health implications of methamphetamine contamination, engage with the external stakeholders that have the greatest influence, and explore some practices that are currently used by industry members.

Firstly, it was discovered that there was limited published literature on exposure to methamphetamine through thirdhand routes, and there was no unified name for it. The term Thirdhand Exposure to Methamphetamine (THEM) syndrome was proposed as a way to identify this exposure route in published documents to improve visibility for researchers, governments and clinicians.

The next step was to identify the practices used by members of the methamphetamine testing and remediation industry. Since there are no standardised methods, accredited courses, or legislation in Australia, the techniques or processes industry members follow was largely unknown. Businesses that advertised testing and remediation services were contacted and asked to participate in a survey and interview. The results highlighted that there is a high level of variation with the locations industry members test within a room, their cleaning techniques, as well as training and experience.

From the surveys and interviews with industry members, it was found that many participants used an immunoassay-type test to initially detect the presence of methamphetamine. These are fast and simple however it is important to know the accuracy and precision of these presumptive test kits. There were 72 tests assessed and while they advertise a detection limit of 0.5 µg per 100 cm^2, many of them returned a positive result below this limit. This was an indication that industry members could be decontaminating properties unnecessarily if they were solely relying on these test kits.

Furthermore, the dispersion and spatial distribution of methamphetamine was evaluated for a property known to be contaminated and then after decontamination had been conducted. The findings from this case study further highlight the need for regulation to enforce consistent approached to assessment and decontamination.

Another aspect to methamphetamine contaminated properties is where members of the public seek advice. This chapter considered factors that impacted Environmental Health Officers (EHOs) to perform their regulatory duties during the peak period of the COVID-19 pandemic, with a focus on contaminated properties. The prevalence of public enquiries to EHOs was also investigated through surveys and interviews which emphasised the need for EHOs to have access to evidence based information.

Each chapter of this thesis recommends the need for standardised methods for testing and cleaning methamphetamine contaminated houses. It has also been proposed the introduction of accredited courses and a regulatory body to oversee the whole industry is necessary to ensure a clear and consistent approach to managing these properties and protect public health.

DECLARATION

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university

2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and

3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Signed:

Emma Kuhn

Date: 15th April 2024

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"A dropout will beat a genius through hard work" – Rock Lee

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STATEMENT OF CO-AUTHORSHIP

The following people contributed to the publication of the work undertaken as part of this thesis. The co-authors are listed in the order that the co-authored publications appears in the thesis

Professor Kirstin Ross

Associate Professor Harriet Whiley

Associate Professor Stewart Walker

Dr Jackie Wright

All above listed contributions equated to no more than 20% of the work necessitated for publication of research manuscripts.

PUBLICATIONS

Kuhn, EJ., Ross, K. E., Walker, G. S., Whiley, H., & Wright, J. 2023, 'Thirdhand Exposure to Methamphetamine Syndrome: Symptoms Resulting From Environmental Exposure to Methamphetamine Contamination Arising From Manufacture or Use', *Journal of Environmental Health*, vol. 86, no. 3, pp. 20-7.

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This thesis is based on the published manuscripts, therefore some repetition between chapters occurs

The thesis was written in Australian English; however, words in American English will appear in some chapters that include published manuscripts due to the language style used by the journal.

1. INTRODUCTION

This chapter provides an overview of methamphetamine and how the contamination of properties can occur. The pathways that lead to methamphetamine contamination being identified by households and the challenges and deficiencies around the regulation of these activities is also explored. The health effects of thirdhand exposure to methamphetamine, and why this is a public health issue will be described.

This chapter includes a peer reviewed article that has been published. It is a commentary article that proposes Third-Hand Exposure to Methamphetamine (THEM) syndrome, as a collective term for the number of non-specific health effects that are associated with methamphetamine exposure.

1.1 Methamphetamine

Amphetamine-type stimulants (ATS) are synthetic, psychoactive drugs that activate and stimulate the central nervous system (Dragan et al., 2021; Leal Cunha et al., 2021). Of this broad range of ATS drugs, the commonly used narcotics include amphetamine, methamphetamine, 3,4-methylenedioxyamphetamine (MDA) and 3,4-methylenedioxymethamphetamine (MDMA) (Lendoiro et al., 2017). Methamphetamine can be found in four main forms; whiteish powder, a sticky, brown wax, pills, and a crystalline form, also known as 'ice' (Degenhardt et al., 2008). The crystalline methamphetamine is typically used for inhalation or injection due to the high level of purity (Degenhardt et al., 2017).

1.2 Clandestine laboratories

The manufacture of illicit drugs is a growing concern worldwide (Dragan et al., 2021; Leal Cunha et al., 2021). In Australia, it is estimated that only 1 in 10 clandestine methamphetamine labs are discovered by law enforcement (Newell, 2008). Clandestine laboratories can vary in size, from large production scale to transport elsewhere, medium sized to supply the local market, and small scale for a few individual methamphetamine users (Shukla & Bartgis, 2008; Willis et al., 2006). Methamphetamine labs have been discovered in residential properties, farms, sheds, hotels, short term accommodation, and car boots (Granholm & Olszewski, 2007; Wright et al., 2016b). There are hundreds of different methods to manufacture methamphetamine (Wright, 2009). The manufacturing process often involves the use of chemicals that are often corrosive, flammable and carcinogenic (Bureau of Justice Assistance, 1993; Cameron, 2002; Mayer & Miskelly, 2022). However, due to the clandestine nature of illegal drug labs, these are chemicals that can be sourced from general hardware stores or online under the guise of legitimate uses.

1.3 Drug use

In addition to local manufacture, importation of methamphetamine can also occur via international mail, air travel, and sea cargo (Australian Criminal Intelligence Commission, 2021). In 2021, United Nations Office

on Drugs and Crime (UNODC) reported there was a combined 393 tons of methamphetamine seized across 150 countries around the world (United Nations Office on Drugs and Crime, 2023b). In Australia, a National Wastewater Drug Monitoring Program is conducted to analyse the consumption of illicit and pharmaceutical drugs and covers approximately 57% of the population (Australian Criminal Intelligence Commission, 2022). The latest figures estimated 10.585 tonnes of methamphetamine consumed during 2022-2023 which is a 17% increase or 1.5 tonnes from 2021-2022 (Australian Criminal Intelligence Commission, 2024).

Globally, there were an estimated 36 million amphetamine and methamphetamine users in 2021, which can be categorised by administration route injection, ingestion, and inhalation (United Nations Office on Drugs and Crime, 2023a). In the most recent World Drug Report from United Nations Office on Drugs and Crime (UNODC), found that methamphetamine is the third most commonly used drug in the world after cannabis and opiates (United Nations Office on Drugs and Crime, 2023b).

1.4 Contamination

1.4.1 Manufacture

The chemicals used to manufacture methamphetamine in clandestine labs, release volatile organic compounds (VOCs) during the cooking process (Mayer & Miskelly, 2022). Given the clandestine operations of illicit drugs, labs are not well ventilated as to avoid discovery (Wright et al., 2016b). This results in VOCs and residual methamphetamine to be dispersed and distributed in the localised environment, such as a bedroom or car (Martyny et al., 2004; Martyny et al., 2008). While the VOCs released vary depending on the cooking method used, residual methamphetamine remains a consistent contaminant (Mayer & Miskelly, 2022).

1.4.2 Smoking

Personal use of the drug via smoking also releases methamphetamine vapours into the air. Pharmacokinetic studies have estimated the bioavailability of smoked methamphetamine is between 37% to 67% (Harris et al., 2003), or 90% from another study (Cook et al., 1993). Thus, it is between 10% and 63% that is exhaled or remaining within the apparatus. It is this exhaled portion that does site contamination from smoking to have between 67% to 90% bioavailability (Cook et al., 1993; Harris et al., 2003), thus indicating that contamination from smoking must occur over time. In addition, it has also been shown that smoking methamphetamine has a social component where people enjoy and share the experience (Green & Moore, 2013; Jozaghi et al., 2016; McKetin et al., 2005). Thus, a group of several people sharing paraphernalia and socially smoking within a property at the same time would result in levels above accepted levels (Martyny et al., 2008).

Household furnishings and personal items can become contaminated when they are exposed to the manufacture or use of methamphetamine. This has been demonstrated this through simulated smoking

and manufacture research (Bitter, 2016; Martyny et al., 2008; Van Dyke et al., 2009). Methamphetamine residues become absorbed into porous fabrics and reside on the surface of non-porous surfaces (Abdullah & Miskelly, 2010; Morrison et al., 2015; Poppendieck et al., 2015). Wright et al. (2019) found that possessions that were moved into a property became contaminated with methamphetamine despite the cessation of cooking (the house had been purchased by new owners) when introduced to the property. While contamination of possessions is a serious concern, the main problem lies in the contamination of structural components of a property that cannot be readily removed, such as gyprock or plasterboard for the walls and ceiling.

1.5 Exposure

The health effects of using methamphetamine, such as cardiovascular complications, high blood pressure, and respiratory issues are experienced by users and have been well documented. This exposure type is known as first-hand exposure (Degenhardt et al., 2017). Second-hand exposure occurs when a person is physically present while methamphetamine is manufactured or smoked (Haefele, 2012). This situation often involves children at the property that are subsequently medically assessed, thus the health effects have also been well researched and documented (Chang et al., 2004; Farst & Bolden, 2012; Messina et al., 2014). Third-hand exposure occurs when a person is come in contact with contamination that has previously occurred in a property (Wright, Kenneally, et al., 2020). This is discussed in detail below (Kuhn et al., 2023).

Thirdhand Exposure to Methamphetamine syndrome: Symptoms resulting from environmental exposure to methamphetamine contamination arising from manufacture or use

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1.6.1 Abstract

Thirdhand exposure to methamphetamine occurs through contact with environments that have become contaminated during manufacture or use. This is a serious emerging public health concern. Exposure can cause adverse health effects in unwitting residents, particularly children. As an increasing number of reports appear in the literature, we propose “Thirdhand Exposure to Methamphetamine syndrome” as a collective term to describe the various non-specific symptoms that are related to methamphetamine exposure. This will provide a searchable keyword to facilitate coordination of research to better understand the health related consequences of exposure to methamphetamine resulting from manufacture and use.

1.6.2 Introduction

Methamphetamine usage has been described as a global epidemic (Chomchai & Chomchai, 2015; European Monitoring Centre for Drugs and Drug Addiction & Europol, 2022; Hansell, 2008; Jones & Comparin, 2020; Pisarski, 2021). Worldwide it is the second most commonly used illicit drug and the most commonly manufactured amphetamine-type stimulant (ATS) (Bijlsma et al., 2021; European Monitoring Centre for Drugs and Drug Addiction & Europol, 2022; Jones & Comparin, 2020; Perez et al., 2022; Stoneberg et al., 2018). Recent reports indicate an increase in both usage and the incidence of overdose (Han et al., 2021; Young et al., 2019). Many countries conduct national drug surveys on an annual basis that consider a range of factors including sociological demographics, substance abuse and stage of addiction (European Monitoring Centre for Drugs and Drug Addiction & Europol, 2022; Substance Abuse and Mental Health Services Administration, 2020; Sutherland et al., 2022). As a result, the dose response and impact of methamphetamine on first-hand drug users has been extensively researched. There are also newspaper articles that highlight drug fuelled violence, trafficking and drug busts by police (Rawstorne et al., 2020). Second-hand exposure is also reasonably well defined as it relates to the cohort of people, especially children, that are present during the manufacture or use of drugs (Holitzki et al., 2017; Meays et al., 2019). This often includes family members and children that reside at the same property.

Both the manufacture and the personal use (smoking) of amphetamine-type stimulants such as amphetamine, methamphetamine and 3, 4-methylenedioxymethamphetamine (MDMA) can result in environmental contamination. Even though amphetamine is structurally similar, methamphetamine has a greater effect on dopamine levels and the corresponding transporter proteins (Chiu & Schenk, 2012). Methamphetamine is the ATS most commonly smoked, as MDMA is usually taken in tablet form or snorted intranasally, thus, methamphetamine is the main ATS of concern for thirdhand exposure (Meyer, 2013).

Methamphetamine use can take place in a range of locations including household properties, hotels, public bathrooms, and vehicles (Cherney et al., 2006; Green & Moore, 2013; Hannan, 2005). This leads to porous materials such as carpet and soft furnishings (including bedding) absorbing these methamphetamine

residues (Morrison et al., 2015; Wright et al., 2019). Furniture, benchtops, interior walls, and other impermeable surfaces can have residual deposits that can be mobilized through air movement or foot traffic (Bitter, 2016; Martyny et al., 2007; Wright et al., 2019). Recent research has also demonstrated that newly introduced furniture can also absorb existing methamphetamine contamination from within a property (Wright et al., 2019). Thus, residents move into a property and are unwittingly exposed to these methamphetamine residues from manufacture or smoking, which is considered thirdhand exposure. This exposure can cause significant, but poorly defined, health effects (Wright, Symons, et al., 2020). Currently, there is limited research of the extent of these health impacts, however the research available has identified a range of symptoms associated with exposure. We consider that there needs to be a collective term to describe the symptoms of thirdhand exposure to methamphetamine. We propose Thirdhand Exposure to Methamphetamine (THEM) syndrome as a collective term to describe the various non-specific symptoms that are related to methamphetamine exposure. This term will enable better tracking and collation of future research, which will inform best practice in regulation and in understanding these health effects.

1.6.3 Thirdhand Exposure Symptoms

A recent study analyzed 63 individuals that had previously resided in a methamphetamine contaminated property (Wright, Kenneally, et al., 2020). The symptoms and housing situations were documented and characterized for the 25 case studies. The individuals consented to hair analysis and permitted the property to be tested for methamphetamine. None of the participants were using or manufacturing methamphetamine themselves. 65 The health effects varied from short-term to chronic symptoms, and the time spent and/or lived at the property ranged from a few days to 10 years (Wright, Kenneally, et al., 2020). The symptoms were self-reported, however each were verified by health professionals, such as the family general practitioner or school nurse (Wright, Kenneally, et al., 2020). Behavioral and cognitive issues (79 and 65%) and sleeping difficulty (72 and 68%) were the most prevalent health effects recorded for under 21’s and adults respectively (Table 1).

Table 1. Summary of Symptoms Experienced by Residents After Thirdhand Exposure to a Methamphetamine-Contaminated Property and by Residents Living in a Former Clandestine Laboratory

Symptom	Individuals Reporting Symptoms (% of Total Individuals)		
	Children and Adolescents (*n* = 29) (<21 years) # (%)	Adults (*n* = 34) (>21 years) # (%)	Adults (*n* = 27) (Residing in a Former Clandestine Laboratory) # (%)
Behavioral and cognitive issues	23 (79)	22 (65)	2 (8) *
Sleeping difficulty	21 (72)	23 (68)	–
Respiratory issues	18 (62)	18 (53)	11 (39)
Skin problems	16 (55)	19 (56)	–
Eye problems	16 (55)	20 (59)	2 (7)
Nausea or vomiting	16 (55)	20 (59)	5 (19)

*Dizziness was the reported symptom, but could also be categorized as a cognitive issue

(Thrasher et al., 2009; Wright, Kenneally, et al., 2020).

Thrasher et al. (2009) published health effects experienced by people exposed to methamphetamine laboratories (where cooking had taken place), which included residents living in former clandestine labs. The six most reported symptoms from adult residents in this study were headaches, respiratory issues, nausea, cough, eye problems and dizziness (Thrasher et al., 2009).

Given that the research is limited, for the purpose of characterizing symptoms associated with thirdhand exposure, both manufacture and smoking of methamphetamine have been included in the table. The authors recognize there may be other symptoms not mentioned, so this should be considered a non-comprehensive list (Flannery et al., 2006; Matteucci et al., 2007; Smith et al., 2015).

1.6.4 Dose-Response Relationship

The term dose-response refers to a concentration or dose of a toxin that will cause an effect in the subject of a particular measurable response (endpoint). Dose response curves generally assumes a sigmoidal shaped curve with increasing dose resulting in increasing effect (Vallero, 2010). There are difficulties in applying this model to methamphetamine. The first is the lack of data about exposure and effect (or symptoms), and the second is the non-specific nature of the symptoms. Both these impediments will be addressed to a degree by naming the syndrome and facilitating information collation.

When establishing guidelines to protect public health, observational research studies are used to identify the No Observed Adverse Effect Level (NOAEL) and/or the Lowest Observed Adverse Effect Limit (LOAEL). While it is important to include both quantitative and qualitative results, it can be challenging to determine an exact threshold due to variation between individuals (Eaton & Gilbert, 2008; Ochoa, 2018). The vulnerability of the population that may be exposed is considered in the use of uncertainty factors, which are applied to the threshold (NOAEL or LOAEL). Establishing a LOAEL from observational studies has been identified by a number of researchers and manuscripts, however the research available is limited (Fahmi et al., 2010; Mayer & Miskelly, 2022; Thrasher et al., 2009; Wright, Kenneally, et al., 2020).

Hair samples, which have long been used as evidence in the court of law for cases involving illicit substances (Kintz, 2017), provides valuable information about the time frame and levels of methamphetamine a person has been exposed to. Recent research has shown that environmental contamination from illicit drugs can be established through hair analysis (Kintz et al., 2020; Kintz et al., 2021). In general, increasing concentrations have been found in the hair, with increasing levels of exposure (Han et al., 2010; Han et al., 2011; Polettini et al., 2012; Wright, Kenneally, et al., 2020). Segmented hair sections were found with higher concentrations than the external hair wash solution indicating the difference between drugs settled on the outside of hair and drugs incorporated in the hair matrix through ingestion (Kintz, 2017; Kintz et al., 2021). In addition variation in concentrations from the root to the tip of

the hair demonstrated that the hair matrix captured the drug as it grew and that the contamination varied over a period of time (Kintz et al., 2021).

1.6.5 Syndromes and Acronyms

Establishment of a defined term to describe the health consequences of thirdhand exposure to methamphetamine is needed to raise awareness, facilitate data collection, improve diagnoses and future research into the potential long-term health consequences. Calvo et al. (2003) have defined a syndrome as a group of known symptoms that can be attributed to a specific illness, even when the complete associations for that ailment may not be fully established. Other syndromes have been defined and allocated an acronym for future identification in research. For example, Chronic Fatigue Syndrome (CFS) (Brurberg et al., 2014), Irritable Bowel Syndrome (IBS) (Chey et al., 2015), and Sick Building Syndrome (SBS) (Redlich et al., 1997), are just a few examples of a syndrome classification with a number of non-specific symptoms.

Sick building syndrome has a number of similarities to thirdhand exposure to methamphetamine, and so is described in some detail below. In the 1980s, the World Health Organization characterized Sick Building Syndrome as a combination of symptoms that are expressed through multiple organ systems when people are exposed to an enclosed, built structure, such as an office building, hospital, or school (Redlich et al., 1997; Runeson-Broberg, 2020). Similar to exposure to methamphetamine, the symptoms are non-specific. Individual's reported headaches, lethargy, itchy, watery eyes, nasal congestion and skin irritation, which are commonly associated with other illnesses (Burge, 2004). It has been documented that several factors increase the prevalence of SBS within a cohort, which includes allergies, sex, temperature, ventilation, outdoor air pollution and volatile organic compounds (Mentese et al., 2020; Runeson-Broberg, 2020; Saijo, 2020). Overall, it highlights the range of indoor air quality requirements and how it varies between individuals. As such, like SBS, it is reasonable to presume there are some members of the public that have not reported health issues or attributed them to another illness (Runeson-Broberg, 2020). Exposure levels are dependent on the individual's risk factors, activities and exposure times (Kintz et al., 1995; Tsanaclis & Wicks, 2008; Wright, Kenneally, et al., 2020). However, in conjunction with self-reported symptoms, exposure to ATS contamination can be verified through quantitative sampling of blood, urine, hair and environmental sampling (Kintz et al., 1995; Tsanaclis & Wicks, 2008). The authors of this article propose the term Thirdhand Exposure to Methamphetamine (THEM) syndrome, as a name for the range of health effects experienced by individuals due to contamination from ATS, specifically methamphetamine.

1.6.6 Current Situation

Research has established that there has been an increase in child autopsies with methamphetamine present in their system (Kenneally & Byard, 2020; Tse et al., 2020). There were seven case studies identified

by forensic scientists in South Australia (SA) and eight from New Zealand (NZ) (Kenneally & Byard, 2020; Tse et al., 2020). Of these cases, six of the seven from SA and all of the eight from NZ were under the age of 12 months. Through blood analysis, both studies determined there was no deliberate ingestion, and there was a known cause of death for all except two cases from SA. Thus, these infants were exposed passively in utero, through breastmilk, formula, or via environmental exposure (Kenneally & Byard, 2020; Tse et al., 2020). There have been several studies investigating methamphetamine exposure in children (Castaneto et al., 2013; Flannery et al., 2006; Kintz et al., 1995; Tsanaclis & Wicks, 2008; Wright, Kenneally, et al., 2020), however, future research is needed to determine the health burden via thirdhand exposure. This situation is exacerbated by a housing shortage in many countries worldwide (Brill & Raco, 2021; Lima, 2021; Massimo, 2021; Richardson, 2022). As a result, sometimes housing is rented or sold without sufficient inspections (Ullah & Sepasgozar, 2020). Additionally, a detailed account about a property's illicit drug history is not available even where law enforcement was involved due to privacy laws. In Australia, it is estimated only 1 in 10 clandestine laboratories are discovered, meaning many go undetected (Degenhardt et al., 2017) and rarely, if ever, is a house assessed due to methamphetamine use alone. In summary, the turbulent housing market may potentially result in an increase in THEM syndrome.

Furthermore, with the increase in roadside random drug testing and workplace testing for illicit drugs (Bade et al., 2018; Love et al., 2022; Mills et al., 2021; D. E. Smith et al., 2021), there are other unintended consequences of THEM syndrome. Residents that are exposed to methamphetamine contamination could potentially run the risk of testing positive for a workplace drug test (Buzby et al., 2021; Kapur & Aleksa, 2020; Tremonti & Haber, 2021), which would have numerous social and physiological consequences. This issue is further complicated by the potential for THEM syndrome to occur through an individual's workplace, such as, police or social workers unknowingly entering contaminated properties (Hannan, 2005; Norman et al., 2021; Witter et al., 2007).

1.6.7 Recommendations for the Environmental Health profession

The environmental health profession is profoundly local (Rodrigues et al., 2021). Environmental Health Officers/Practitioners (EHO/EHPs) work on the front line to protect public health and can be the first point of contact for individuals concerned about methamphetamine contaminated properties (Kuhn, Walker, Wright, et al., 2021). Environmental health is best positioned as a profession to take on the challenge of regulating this public health threat. However, currently there are many businesses working in this space. In Australia, it has been found that there is a concerning lack of industry regulation and some businesses have been found to have conflicts of interest (Kuhn, Walker, Whiley, et al., 2021). For example, some companies have been conducting the initial testing for a property, the decontamination process and then also the validation testing to confirm that their decontamination process worked (Kuhn, Walker, Whiley, et al.,

2021). The environmental health procession should advocate for these processes to be conducted by independent businesses to ensure no bias.

There are also several uncertainties that must be considered when assessing the public health risks associated with managing methamphetamine contamination and future research is needed to inform a best practice. For example, exposure time is one of the essential factors that can impact the health outcome of the individual, thus contamination within residential properties is the main concern. People, especially young children, spend a significant portion of time everyday in the home (Wright, Kenneally, et al., 2020). Residues in public places, such as shops or public restrooms is less of a concern due to the short exposure time in that space. A syndrome name will both facilitate the collation of information, and raise awareness of the issue, which will support the environmental health profession efforts in regulating this space to protect public health.

1.6.8 Conclusion

Currently, there many gaps in knowledge regarding environmental contamination with methamphetamine from use and manufacture, and associated health effects. Future research is needed to further characterize the symptoms and potential long-term health consequences of thirdhand exposure to methamphetamine. This syndrome definition will focus future research, provide a searchable keyword and enable relevant studies to be more easily identified and tracked by medical professionals, researchers and government officials.

1.6.9 Author Contributions

Conceptualization, E.J.K., K.E.R. and H.W.; investigation, E.J.K., and J.W.; writing—original draft preparation, E.J.K., K.E.R., G.S.W., H.W., and J.W.; writing—review and editing, E.J.K., K.E.R., G.S.W., H.W., and J.W.; supervision, K.E.R., H.W., G.S.W., and J.W. All authors have read and agreed to the published version of the manuscript.

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1.6.12 Conflicts of Interest

The authors declare no conflict of interest.

1.7 Testing and remediation services

The acceptable limit of methamphetamine contamination varies depending on the country, state and territory. In the United States, California has a limit of 1.5 µg per 100 cm^2, Colorado has 0.5 µg per 100 cm^2, and North Carolina has 0.1 µg per 100 cm^2 (Department of Toxic Substances Control, 2019; Hazardous Materials and Waste Management Division, 2003; Montana Department of Environmental Quality, 2005).New Zealand had a limit of 0.5 µg per 100 cm^2, in 2017 a standard of 1.5 µg per 100 cm^2 was developed, and there is currently a proposition for an increase to 15 µg per 100 cm^2 (Institute of Environmental Science and Research Ltd, 2016; Kuhn et al., 2019; Ministry of Housing and Urban Development, 2022). Australia took a national approach and developed guidelines using a risk based assessment. The Clandestine Drug Laboratory Remediation Guidelines determined that any area with a test result above 0.5 µg per 100 cm^2 requires remediation (Australian Crime Commission, 2011). The next step in the process for a remediation technician to decontaminate the property, and then the property is re-tested to ensure the decontamination was successful and then a validation certificate is issued (Australian Crime Commission, 2011).

The Australian guidelines provide a framework starting with the prompt for the initial assessment, through to the validation of the decontamination (Australian Crime Commission, 2011). The descriptions however, are very broad and often open to interpretation which leads to the issue of regulation. The Australian guidelines recommend an experienced expert with tertiary qualifications in environmental engineering, environmental science, environmental health or occupational hygiene (Australian Crime Commission, 2011). Unfortunately, the reality is that there are many different businesses that offer testing and/or remediation for methamphetamine contamination and robust training is not available (Kuhn, Walker, Whiley, et al., 2021). Another difficult aspect is there are no standardised techniques, equipment or cleaning chemicals available for this industry to use (Kuhn et al., 2019; Owens, 2017). There is no methodology standardisation or regulation for the industry members, therefore there is no accreditation or accredited training opportunities. Fortunately, it is accepted practice that a qualified occupational hygienist validates the success of the decontamination with another set of tests, before certifying it. This is a unique combination of challenges for those that need to make the judgement that a property is safe for human habitation again.

1.8 Environmental health officers

Environmental Health Officers (EHOs) are responsible for regulating and educating an array of public health initiatives to businesses and residents of a local council area. The overarching role of EHOs is public safety which requires them to pivot from water quality to infection control, food safety, emergency management, climate change and chemical exposure (Whiley et al., 2018). If a member of the public has concerns or

complaints about food safety, noise, or strange odours, they would contact the environmental health department at their local council.

When law enforcement uncovers a clandestine lab, they send a notification to the environmental health department for that council area (Al-Obaidi & Fletcher, 2014). This instigates the EHO to put a notice on the property that states the house is not fit for human habitation. The notice is served to the property owner and then they must decide how and when to engage with a testing and/or remediation expert. Once the property has been decontaminated, then it must be confirmed with further testing before a validation certificate is issued.

If a concerned resident contacts their local council with suspicions that their property is contaminated with methamphetamine, the process is not as straight forward. If a resident is renting the property, then it would be recommended that they contact their agent or owner. The property owner would be advised to seek a qualified person to test the house for contamination or to purchase a kit and conduct the testing themselves. At this point, if a positive result is returned, then a remediation expert would be the next person to contact. However, since this process is not managed by an EHO, owners often clean it themselves or choose to ignore it. It is obviously in the best interest of those owners that currently reside within the contaminated property, to have it adequately cleaned.

These two methamphetamine contamination methods are very different, but ultimately, the suspected pathway is largely unregulated. As mentioned above, EHOs typically only see and manage clandestine lab notifications which is directed by the Australian guidelines, however it is reasonable to presume that the local environmental health department would also guide methamphetamine contamination cases given their role in other areas.

2. AIM AND OBJECTIVES

2.1 Aim

Methamphetamine contamination arising from smoking and the manufacture of the drug remains an under recognised public health issue. The aim of this research was to investigate the assessment and remediation of methamphetamine contaminated of properties in Australia. This included the role of external stakeholders, current industry practices and an investigation into the spatial distribution of methamphetamine within a contaminated property pre and post remediation.

2.2 Objectives

- Review current published literature for the associated symptoms and health impacts of thirdhand exposure to methamphetamine to establish a collective term for the symptoms (Thirdhand Exposure to Methamphetamine [THEM]).

- Through surveys and interviews, identify the testing methods, chemicals and equipment currently used by industry members within the methamphetamine testing and decontamination industry.

- Conducted laboratory assessment to evaluate the efficacy of a range of presumptive test kit brands used by industry to detect the presence of methamphetamine in properties.

- Conduct environmental sampling to determine the spatial distribution of methamphetamine contamination in a residential property and ascertain the differences between sampling areas before and after remediation.

- Through a survey and interviews, understand methamphetamine contamination from an Environmental Health Officer perspective through assessing the prevalence of public enquiries, establishing differences between states and territories, and exploring the challenges due to COVID-19.

2.3 Thesis structure

This thesis is comprised of 6 chapters; an introduction, an aim and objectives chapter, four research chapters, and a discussion and conclusion chapter. There is also supplementary information included in the Appendix.

3. OVERVIEW OF CURRENT PRACTICES IN THE METHAMPHETAMINE TESTING AND DECONTAMINATION INDUSTRY: AN AUSTRALIAN CASE STUDY

This chapter describes the current practices used to test, remediate and validate methamphetamine contamination by industry members in Australia. This industry has no regulation, accreditation, thus there is no standardised training or methods used. As a consequence, the techniques used in the methamphetamine testing and decontamination industry are varied and largely unknown. This study characterised the current industry practices and identified areas for future research and recommendations for regulators to standardise this profession.

This manuscript was published during the course of the PhD.

Overview of Current Practices in the Methamphetamine Testing and Decontamination Industry: An Australian Case Study

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3.1 Abstract

To better protect public health from third-hand exposure to methamphetamine, it is important to understand the techniques and current practices used within the methamphetamine testing and decontamination industry in Australia. A survey was conducted focusing on business owners that advertised testing and/or remediation services online. They were also invited to participate in a follow-up phone interview upon completion. The survey demonstrated that testing and decontamination methods were highly varied, which was expected for an industry with no regulation. Most companies offered methamphetamine testing and remediation which could be a conflict of interest. Participants also shared personal experiences, including the conduct of other industry members, demonstrating both poor practice and/or the competitive nature of the business. Participating business owners were following Australian guidelines to the best of their ability, and many are advocates for regulation to be implemented within the industry. This would address the inconsistencies between companies and establish trust for industry members and the public. It would also provide significant public health protection, which is currently lacking. A more consistent approach to the testing and remediation of methamphetamine contamination, aided by regulation, would address the significant risk to public health caused by third-hand exposure to methamphetamine.

3.2 Introduction

Methamphetamine contamination of properties is an emerging public health issue. Methamphetamine is a highly addictive amphetamine-type stimulant that is commonly used and manufactured within residential properties (Dietze & Peacock, 2020; Weisheit & Wells, 2010). This illegal drug can be inhaled via smoke, ingested, or injected (Sheridan et al., 2006), and has different forms, including a crystalline structure, a waxy base, and a whiteish powder (Chomchai & Chomchai, 2015). During the illegal manufacturing of methamphetamine or through personal usage (smoking), methamphetamine vapours are released into the air and absorbed by materials such as walls and furniture (Wright et al., 2019). It has been shown that methamphetamine residues can remain present for over five years and contaminate new furniture introduced to the property (Wright et al., 2019). These residues can significantly impact resident's behaviour, cognitive function, and general health (Wright, Kenneally, et al., 2020). Through chronic exposure, health effects include eye and skin issues, headaches, respiratory effects, and sleep disturbances (Rindelaub & Miskelly, 2019; Salocks, 2009; Wright, Kenneally, et al., 2020). The environmental contamination exposure time in adults and children is highly dependent on the individual, the activities they undertake, and the time spent within the property (Wright, Kenneally, et al., 2020). Due to the broad nature of the symptoms associated with third-hand exposure to methamphetamine, the lowest observed adverse effect level is difficult to determine with the existing data. Third-hand exposure to methamphetamine remains an under-researched area of environmental health.

The methamphetamine remediation industry is comprised of occupational hygienists and other testing companies (for testing and validation) and remediation businesses. Many companies within the methamphetamine remediation (MR) industry have MR as an added service to existing cleaning business models. Subsequently, equipment, processes, and chemicals from domestic or commercial cleaning have also been adapted to MR. In Australia, when a property is suspected of methamphetamine contamination, the tenants or owners seek advice from a testing and/or remediation company that will conduct an assessment on the level of contamination. Prior to any cleaning, a Remediation Action Plan will be produced to define the extent of remediation required. The property is then remediated, and to ensure it has been adequately cleaned, a validation test will be conducted to assess any residual contamination. In line with Australian guidelines, qualified occupational hygienists conduct the validation tests and determine whether the property has been decontaminated.

In Australia, advice and recommendations are determined through the Australian Clandestine Drug Remediation Guidelines (AG) and, more recently, the Australian Voluntary Code of Practice (VCOP); however, there is currently no legislation or regulation for MR (Australian Crime Commission, 2011; Wright et al., 2019). As a result, this industry has no mandatory training, nor standardised techniques that are specific to MR. In Australia, the contamination investigation level is for surfaces only, and is 0.5 g per 100 cm^2 (Australian Crime Commission, 2011); New Zealand standard's limit is 1.5 g per 100 cm^2 (Standards New Zealand, 2017). In the United States, these limits vary depending on the state, from 0.05 g per 100 cm^2 in Arkansas to 4.0 g per 100 cm^2 in Colorado (Arkansas Department of Environmental Quality, 2008; Hazardous Materials and Waste Management Division, 2003; Kuhn et al., 2019). These risk-based limits have been adopted as the remediation criteria based on what is considered to be an acceptable level. These standards offer guidance; however, they are not enforceable in Australia nor New Zealand as they have not been incorporated into legislation. The regulation of remediating methamphetamine-contaminated properties is critical to protect human health from this emerging public health risk.

The aim of this study was to determine the methods, treatments and protocols currently used within the MR industry, using Australia as a case study. A secondary aim was to gain insight into the general practices of cleaning companies offering an MR service to the public. To conduct this, companies advertising MR services were contacted and asked about their activities through an online survey, followed by one-on-one interviews, where possible.

3.3 Materials and Methods

3.3.1 Identifying Potential Participants

Companies advertising an MR or testing service in Australia were identified using the search engine Google® (Google, Menlo Park, CA, USA) And the following key search terms were used: methamphetamine OR 'clandestine lab' OR 'meth lab' AND remediation AND contaminated OR contamination AND Australia

AND company OR business. A list was generated with company contact details. Owners with multiple business names were only listed once.

3.3.2 Survey Questions

The research methodology and survey were approved by the Flinders University Social and Behavioural Research Ethics Committee (SBREC) in South Australia (Project number 8634). The survey was conducted online (Qualtrics® software (Qualtrics, UT, USA)) and included single-answer multiple-choice questions, multiple-answer multiple-choice questions and free-text questions (Appendix B). The varied question styles were designed to permit the participant to add as much or as little detail for questions based on their experience or practice. Using only multiple choice questions would have hindered openly honest answers; however, they did provide structure and time efficiency for the remainder of the survey (Jackson & Trochim, 2002).

3.3.3 Contacting Companies

To initiate contact with business owners, an email was sent with an introduction, information attachment, and the link to the survey. The Qualtrics® link remained open for two months to allow participants to complete the survey without time pressure.

3.3.4 Phone Interviews

Upon completion of the online survey, participants were given an option to be contacted via phone to provide further details regarding their survey answers. Those participants that indicated that they were willing to participate in a one-on-one interview were contacted by phone for approximately ten minutes to discuss their survey responses. These interviews were transcribed into Microsoft Word® (Microsoft, Redmond, WA, USA) for qualitative data analysis.

3.4 Results

3.4.1 Participants

The online search identified 100 companies involved in methamphetamine remediation in Australia. This included 64 individual business websites and 36 franchise contacts. Of the 64 websites, 14 shared ownership with another business, and of the 36 franchises, 10 franchises owned other locations. There was also one business that no longer existed. Thus, there were 75 individual owners that could be contacted to participate in the study. Of the 75 owners, 40% agreed to participate in the survey, 53% did not respond, and 6.6% expressed they had no interest in the study. Subsequently, 60% of participants agreed to a follow up one-on-one interview.

3.4.2 Survey Results

The location of the largest number of participants was Queensland (39%), followed by Victoria (25%), New South Wales (18%), Western Australia (11%), and South Australia (7%). There were no respondents from Northern Territory, Tasmania, or the Australian Capital Territory.

Provided with a free-text box, respondents were asked what testing and remediation qualifications they had. Participants had been trained in equal numbers through Jena Dyco International (now known as TESA Directive), Decon Systems, and the Institute of Inspection Cleaning and Restoration Certification (IICRC) courses and seminars (Figure 1). IICRC is an international organisation that develops standards and offers certified training for cleaning and restoration industries; Jena Dyco International (now trading as TESA Directive) and Decon Systems are both certified Australian training providers for IICRC courses (Decon Systems, 2021; High Power Cleaning Melbourne, 2017; IICRC, 2021). The remaining answers were equally divided with single responses between companies and training providers, including Amdecon, Hills Laboratory, the Australian Institute of Occupational Hygienists (AIOH), and New Zealand Qualifications Authority (NZQA).

Forty-eight percent of companies reported ‘less than 10’ queries for methamphetamine remediation services per month and 59% of companies cleaned ‘less than 10’ properties in a month. However, the total number of properties cleaned was bimodal, 23% and 57% reporting ‘less than 10’ or 10–50, respectively, and 30% having cleaned 150–200 properties. This demonstrated a clear divide in the respondents which suggests these enterprises are either large or small, and a few medium-sized enterprises.

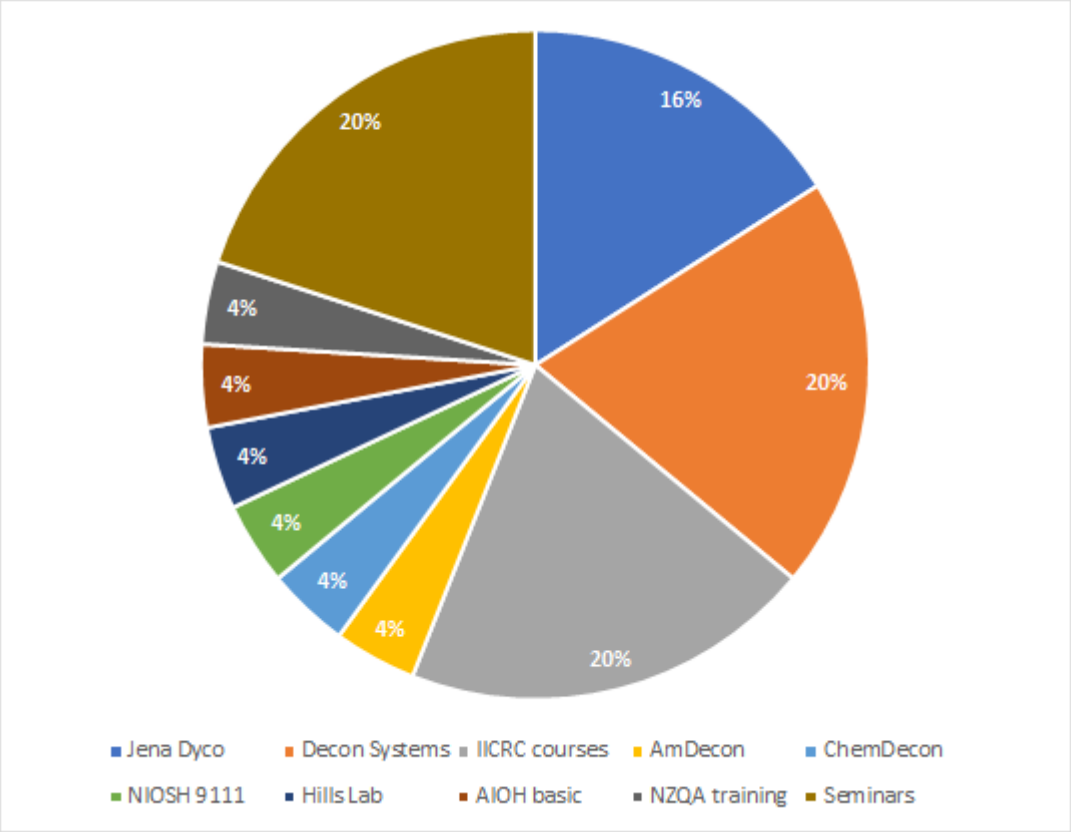
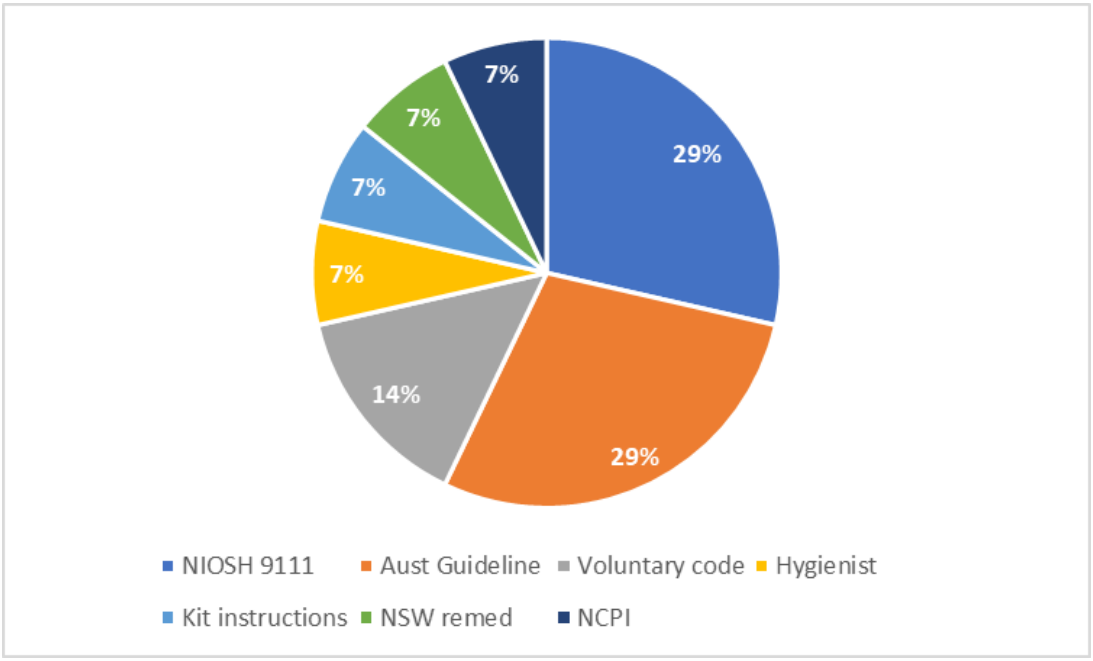


Figure 1. The reported testing and remediation qualifications

3.4.3 Testing Services

Participants were asked what guidelines they followed for their sampling methods and provided a free-text box for their answer. The most common answers were the National Institute for Occupational Safety and Health (NIOSH) Standard 9111, the Australian guideline 2011, and the Voluntary Code of Practice 2019 (Figure 2a). Other single answers included directions from occupational hygienists, test kit manufacturer instructions, and guidance from the National Contaminated Property Investigations (NCPI).

(a)



(b)

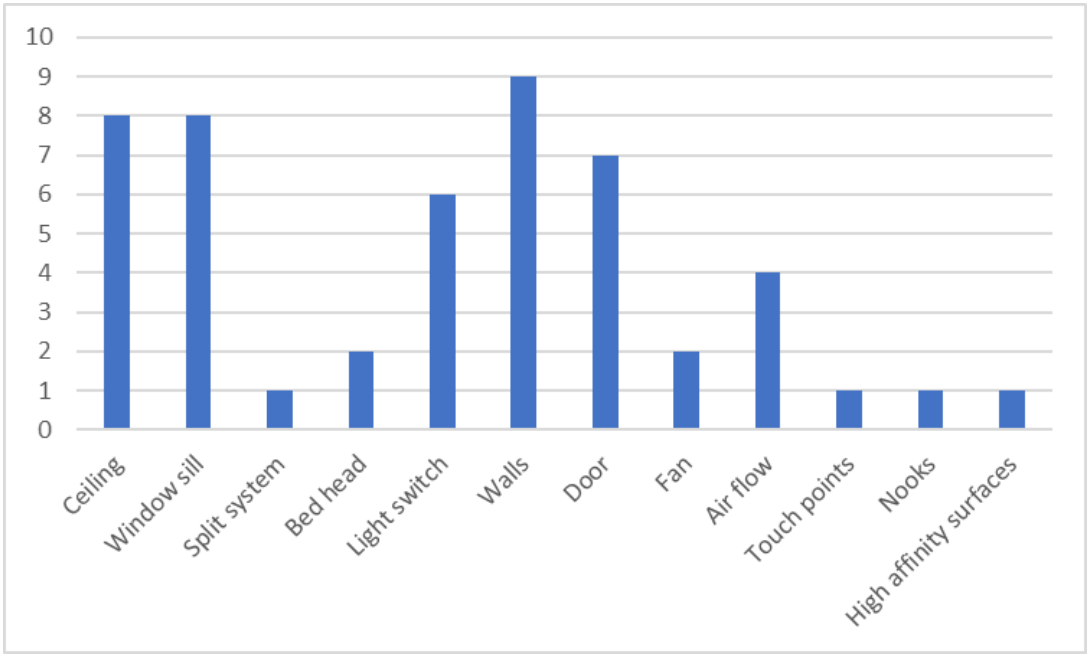


Figure 2. (a) Guidelines followed for sampling; (b) sampling locations in a contaminated bedroom

Companies were asked what services they offered and could select all that applied, which resulted in 76% of participants indicating they offer both testing and remediation while the remainder offered testing (7%) or remediation (17%) exclusively. When asked what type of sampling was used, most companies (44%) used wipe sampling (conducted with gauze wipes and methanol) or 39% used a combination of wipes and presumptive tests (instantaneous presence or absence test). However, there was 17% that used presumptive testing exclusively. For the use of presumptive tests, only 30% stated the tests had been independently validated through a National Association of Testing Authorities (NATA) accredited laboratory. For those using wipe sampling, 46% used discrete samples, 37% used laboratory composites, with 17% using field composite samples.

When sample wipes were used, those held in separate containers and analysed individually were called discrete wipes. Laboratory composite samples also used individually contained wipes but combined small aliquots of the extracts for analysis. Field composites are wipe samples that were contained, transported, and analysed together (Standards New Zealand, 2017). While discrete wipes are the ideal sampling technique, they can easily become a costly screening assessment for the client. Laboratory composite samples can be useful as a cost saving measure and re-assessment of individual samples can be arranged if contamination is present (Wright, 2019). Field composites, however, are multiple samples held together; therefore, they cannot be re-assessed, and re-sampling of the property needs to occur.

Respondents were asked, with a free-text box, to provide an example of where they would take samples from within a contaminated bedroom. The answers were highly varied and covered a range of surfaces and locations (Figure 2b). Respondents were asked how many photos they would take, which resulted in varied answers. Some respondents stated a number, e.g., two per test or four per room, and others stated a number that would encompass all photos given to the client, e.g., 30–100.

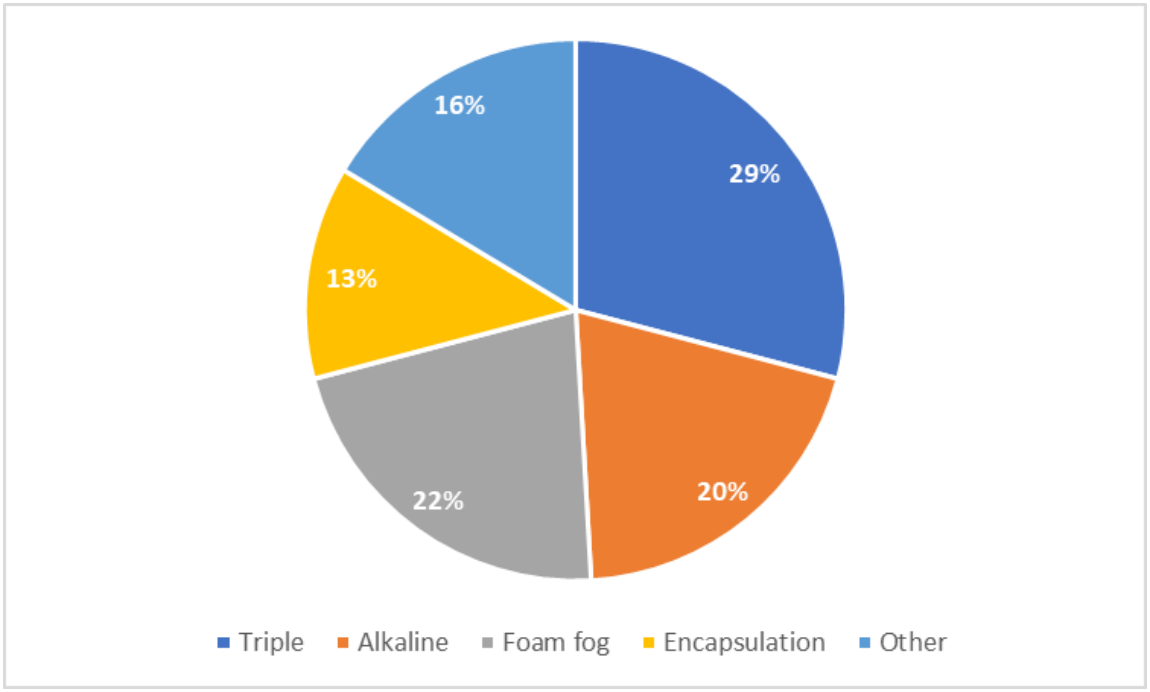
3.4.4 Remediation Services

Seventy percent of respondents stated they prepared a Remediation Action Plan, while the remainder referred to occupational hygienists or the clients preparing the report. Participants were asked whether there were any external factors or stakeholders that would influence surfaces tested and the extent of remediation. This question was focused on contractors and, apart from their own experience, what else had determined the degree of sampling or remediation they would undertake. The AG had the highest response (31%), followed by real estate agents (22%), insurance companies (20%), and the clients (16%), while 11% considered it not applicable.

Participants were asked about the remediation methods used and provided a multiple select option (Figure 3a). The responses predominantly included chemical solutions that were applied directly to the contaminated surface. Triple wash was the preferred treatment, then foam fog and alkaline wash, while encapsulation and other methods had similar response numbers. Fifty percent of participants answered yes

to using multiple treatments together. Although companies predominantly used triple wash, foam, and alkaline wash, 20% of companies used the chemicals in conjunction with other treatments, and the most common drying time frame was 24–48 h. Fifty eight percent of respondents had experienced problems with chemical treatments, and it was commonly due to them being incompatible or unsuitable for a particular surface. Participants were asked whether they had a safety data sheet for the chemicals used. Eighty eight percent stated yes; however, the next question asked if they were able to provide the numbers and fewer than half listed them.

(a)



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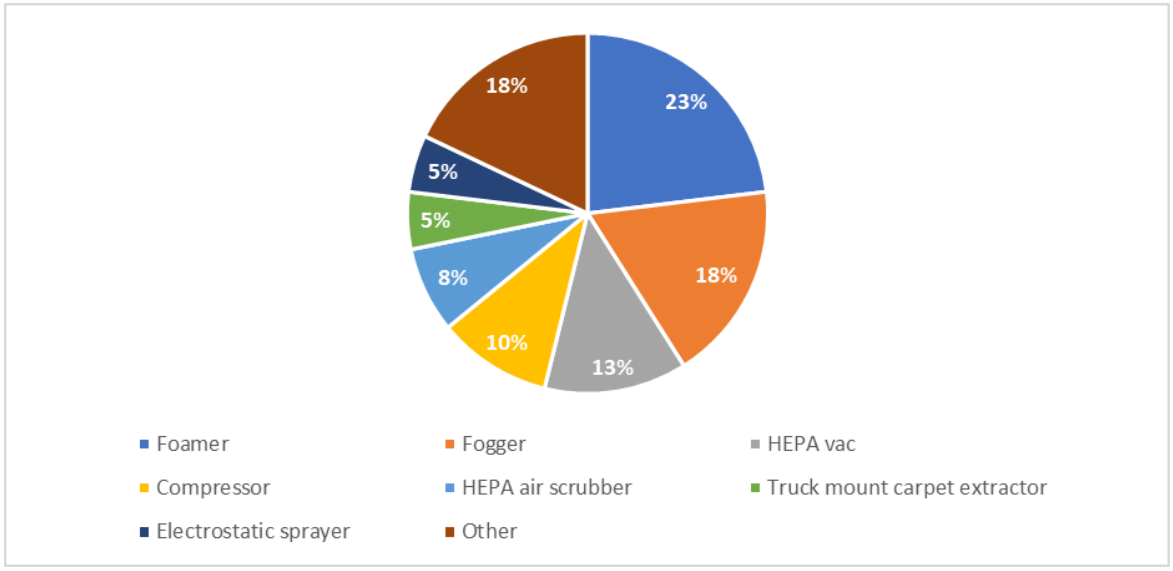

Figure 3. (a) Remediation methods used; (b) equipment used to remediate methamphetamine contamination.

A free-text box was provided to respond to a question about the techniques used by respondents to reduce the risk of cross-contamination during remediation. Containment of the areas while cleaning (26%) was the most common answer, followed by separated sample bags (15%), using a HEPA air scrubber (11%), a partial clean of the whole area (11%), changing gloves (11%), and the use of different equipment (11%). The majority of respondents stated that changing gloves was the main cross-contamination prevention measure when sampling, while others mentioned separating samples and covering contaminated surfaces underneath any equipment.

The results from a question about equipment were highly varied (Figure 3b) and many employed multiple pieces of equipment. The two most common were foamers and foggers with 80% of respondents stating they were cleaned after each use. Foggers generate a fine mist of the cleaning solution while foaming machines use compressed air to produce thick bubbles of cleaning solution. Both pieces of equipment are used in other aspects of the cleaning industry (Decon Systems, 2019; New Life Restorations, n.d.), The remaining 20% of respondents reported cleaning their equipment several times in a day or daily.

With regard to the removal and replacement of electrical appliances from a contaminated property, the results were evenly divided. Participants either stated they would replace all electrical items within a contaminated property, or they would replace items if they were above the recommended 0.5 g methamphetamine per 100 cm^2. However, there was one company that stated they would clean all electrical items.

3.4.5 Remediation Outcome

Approximately half of the respondents stated they had, at least once, returned to a property that they had cleaned. When asked why, in most cases it was because a second treatment was required to achieve a concentration below the recommended levels. Fifty eight percent of respondents stated they had remediated a property that had been insufficiently cleaned by another company, with 46% stating this had occurred between one and five occasions. Ten percent stated 5–10 occurrences, 7% had 10–15, 10% stated 15–20 instances, and 7% stated this had occurred over 20 times.

When respondents were asked whether they had consulted other experts for advice, over half of the respondents had contacted an occupational hygienist (55%), many stated another remediator (24%), and other testing companies. Advice from police, insurance companies and Decon Systems was also sought. Again, the number of occasions ranged from high (20+) to very few (1–5), which could be an indication of the size of the company.

3.4.6 One-on-One Interviews

Businesses were contacted once the survey had been completed to allow respondents to elaborate on their survey responses. During this time, conversations often expanded to their experiences of working within

the remediation industry. While this was not formally part of the methods of the study, this provided an opportunity to gain further insight based on personal experiences, especially with other industry and associated members. There were 18 respondents that selected yes to participating in an interview after the survey. The following is a combination of the discussions with industry members.

Respondents indicated concerns about issues such as inconsistent sampling results between companies, unrealistically low pricing that could not achieve remediation, and the unethical conduct of some other industry members.

> *"A company got a quote from a known dodgy company and contacted me to beat the price. They said the job they wanted done and how much they wanted to pay. I explained that it doesn't work like that and I'm not interested."*

Many business owners travel around Australia to secure work in the remediation industry; however, some have been known to not return to reclean a property even if clearance was not successful. Discussions revealed some companies used fog treatment and chose to, subsequently, follow it with water, which had created water damage to properties and, in some cases, did not allow for an accurate validation test. Secondly, some occupational hygienists have also been known to circumvent the Australian Guidelines and provide inadequate information to their clients.

> *"There was a recent [validation] report that only provided 3 photos. These clients are paying thousands for a test and [get] very little information."*

> *"[The occupational hygienist] said he forgot to re-test the property, but it was ok, he 'visually inspected' it and it was fine."*

Respondents also expressed concern for the safety of their employees. During one conversation, an owner asked whether their employees were at risk when transporting methamphetamine-contaminated furniture and household items to the local rubbish dump. Upon further questions, it became clear that the company was located in a rural area and, therefore, were having to transport waste a significant distance as hazardous waste removal was not available in the area.

Public perception was also a concern for these business owners. One owner from Queensland stated they were commonly asked by clients if they were required to go through a testing company since Queensland Health Department offers a swab testing service. The owner was obliged to explain there was no legal requirement for them to employ the services of a testing company. They stated it was difficult to demonstrate the challenges of presumptive samples and the benefits of using a testing company when the prices were significantly different.

"There is a current trend where clients are buying presumptive tests online and testing themselves before they call anyone. This brings about problems with consistency, awareness of where to test and reliability of the test."

One respondent mentioned that while rental properties were considered high risk for methamphetamine contamination, they had cleaned approximately 150 homes and the majority of them were owner-occupied properties. Another reported they had positive results after testing for methamphetamine within a property management office.

"[We] just cleaned a real estate office, where the manager was smoking meth inside the building. So it's unlikely real estate agents like this will push for property testing in between tenants."

3.5 Discussion

The short, ten-minute online survey with a simple user interface that was transferrable to mobile devices was intended to allow business owners to participate without a large time commitment. The combination of quantitative and qualitative questions involved in the survey was aimed at participants' willingness to share in-depth cleaning and chemical methodology.

3.5.1 Unethical Conduct and Conflict of Interest

The results of the study found that the majority of businesses in the MR industry offered both testing and decontamination services. While it may seem as a natural partnership for the two services, there were ethical implications that must be considered. Business contracts should be based on working for the best interest of the client, both professionally and financially, rather than attracting them through false quality or prices driven by industry competition (Bennett et al., 2013). Unethical behaviour can be real or perceived; regardless, it can impact how the public perceives the validity of the business. Based on business literature, conflict of interest, deliberate misinformation, or disregard of prior agreements are just a few practices that are recognised as unethical (Collewaert & Fassin, 2013). Therefore, each stage of the decontamination process, the screening and detailed assessments, remediation, and the validation sampling should be offered as separate services by individual companies. Establishing and maintaining a trustworthy reputation is essential for the longevity for any industry (Chang et al., 2006).

Recommendations have been determined for presumptive testing kits to be independently validated by a NATA accredited laboratory (Wright, 2019). It is not possible to know the accuracy or precision of a presumptive test without this critical analysis. Therefore, the presumptive test results alone are inadequate to determine the extent of contamination if it was the only method used for detecting methamphetamine. While this method is not strictly unethical, it is not considered best practice.

For results of tests to be analytically valid, a certain number of blanks, controls, and tests for false positives and false negatives with safeguards need to be undertaken (Saitman et al., 2014). A blank is a test performed on a swab that was known to be uncontaminated. A control is a swab taken to the place of investigation but not exposed. False negatives and positives require a certain number of swabs that were sent for a confirmation analysis to determine if a swab was returning either a negative result but had methamphetamine or a positive result when there was no methamphetamine (Keary et al., 2012). These additional tests impose an additional burden in time, resources, and cost. This is an area where unscrupulous companies may cut corners but without these assurance tests the extent of false reporting is not clear.

3.5.2 Lack of Regulation

Currently in Australia, no regulators for the testing and remediation of methamphetamine contamination exist to ensure compliance of the Australian Guidelines. Thus, there is also no simple way for a client to seek a suitable and qualified expert to test or remediate their property. The majority of states and territories were not able to provide a list of reputable testing and remediation companies unless they requested a tender (Department of Finance; Australian Government, 2020); however, the Department of Health in Western Australia issues lists periodically (Government of Western Australia, 2020). The Queensland Health Department offers sampling kits and analytical testing through their NATA accredited laboratory (Queensland Government, 2021); however, testing knowledge and experience is essential in this instance. Having untrained individuals using test kits could result in inaccurate readings. Other concerns regarding methamphetamine contamination in homes is often addressed by the Environmental Health Officers who are under-resourced and have been impacted by COVID-19 responsibilities (Kuhn, Walker, Wright, et al., 2021).

It has been shown that self-regulation can be challenging and that mandated approaches provide structure and compliance (Segerson, 1999; Sharma et al., 2010). For example, to remain compliant with legislative requirements, the food safety industry has adopted auditing strategies that are dependent on the size or franchise status of the company. Auditing can be separated into three segments; self-auditing is based on the individual, internal auditing can be from another sector from within a franchise, and external auditing is from an outside assessor (Kotsanopoulos & Arvanitoyannis, 2017). Both types of internal auditing can provide an outline of issues, while third party auditing would assess the business without any biases or conflicts of interest. Currently, the MR industry is using a self-regulation approach; however, given the public health significance of this issue, external auditing and regulation would be more appropriate.

Many members of the MR industry that were interviewed expressed an interest in, and were willing to advocate for, the establishment of regulatory organisation for the industry. This would provide somewhere for clients to seek advice, accreditation for qualifications and training, and ensure consistency across the

industry through audits and other feedback mechanisms. An example of this is the accreditation and licence classes for asbestos removal which are regulated by each state or territory, but are directed by Safe Work Australia (Gray et al., 2016). NATA is another certifying authority (Wilson-Wilde, 2018) that could potentially provide accreditation for the use of a standard by licenced testing and remediation companies.

3.5.3 Qualifications and Training

Due to the absence of a regulatory organisation for methamphetamine testing and remediation, there are no accredited MR qualifications available. Therefore, the broad list of MR qualifications and courses provided by participants was likely to be exhaustive. Businesses in the cleaning industry broadened their expertise (Alan, 2011) to meet a market demand in methamphetamine decontamination (Decon Systems, 2021; IICRC, 2021).

While not all companies received training from institutions, there were some qualifications—Jena Dyco (now TESA Directive), Decon Systems, and IICRC—that were significantly more common. It has also been acknowledged in the Voluntary Code of Practice (2019), that tertiary education alone is not adequate and that relevant experience within the methamphetamine decontamination industry is paramount (Wright, 2019).

There are training systems that are used to monitor existing companies and to ensure compliance in drug decontamination. In Washington State, Oregon, and Indiana, a mandatory clandestine laboratory cleanup certification has been established to standardise qualifications. These states also have implemented compulsory renewal systems that include refresher courses either annually or every two years (Indiana Department of Health, 2021; Oregon Health Authority, n.d.; Washington State Deparment of Health, n.d.).

3.5.4 Protocols and Guidance

This study found a high level of variation in the methamphetamine sampling/testing methods and cleaning techniques used by Australian companies. This can be expected from an industry without standardised methods and the available guidelines are applied on a voluntary basis (Kuhn et al., 2019). However, there were some aspects, such as cross-contamination reduction measures, that appeared to be universally adopted for both sampling and remediation. This is an indication that some methods used for other cleaning services can be successfully adapted to suit methamphetamine decontamination.

The Australian Guidelines and the Voluntary Code of Practice, released in 2011 and 2019, respectively, provided advice and directions for sampling, testing, and remediation of methamphetamine contamination (Australian Crime Commission, 2011; Wright, 2019). The United States has NIOSH Standards 9111, 9109, and 9106 for the analytical methods (NIOSH, 2011a, 2011b, 2011c), and some states provide guidelines for testing and decontamination. A review from Owens (2017) published in-depth methods and chemicals from a number of U.S. Government documents and cleaning companies. While it offered great insight, the U.S

focus was difficult to obtain comparisons since companies had Proprietary Limited information, and/or they were promoting their own products. New Zealand's unified centralised government allows for the incorporation of a standard into legislation to be a more straight-forward process (Cheyne, 2008). New Zealand released the Testing and Decontamination of Methamphetamine Contaminated Properties (NZS8510:2017) Standard (Standards New Zealand, 2017) and is now moving toward implementing regulations under the Residential Tenancies Amendment Act 2019 (New Zealand Government, 2019). One of the most significant measures that need to be addressed to enable development of a consistent protocol would be for all stakeholders to agree that methamphetamine contamination through personal use, as well as manufacture, is a public health concern. Polarised opinions in this area still remain and this needs to be resolved.

3.6 Conclusions

In Australia and New Zealand, the methamphetamine testing and decontamination industry has grown in response to the awareness of this emerging public health issue. This manuscript provided a foundation for determining common remediation industry practices. These qualitative and quantitative methods can be adopted for other jurisdictions and repeated in their own language. The variation in sampling and cleaning techniques highlights the need for regulation to oversee this industry to ensure consistency within the industry. The establishment of a regulation process would also promote more interdisciplinary collaboration and mitigate unethical practices. Ultimately, the MR industry is comprised of business owners that mainly want to be perceived as an asset and acknowledged that they are working to improve public health. Future research will be aimed at determining the efficacy of the remediation and sampling techniques currently used in the MR industry.

3.7 Limitations

This study was based on a purposive sampling approach to identify MR companies to be contacted. However, participation was voluntary, and this may have introduced some bias and the findings may not be representative of the whole industry. The survey questions were self-driven which allowed the participants to choose what they wanted to answer; however, this resulted in a variation for the interpretation and the number of individual questions answered. The questionnaire design also relied on the attention to detail and honesty of the participants. The available time for business owners to complete the survey was also something to be acknowledged. There were some industry members that stated due to their increased workload from COVID-19 cleaning, they were not able to participate in the study.

3.8 Supplementary Materials

The following are available in Appendix B (Survey).

3.9 Author Contributions

Conceptualization, E.J.K., K.E.R. and H.W.; methodology, E.J.K., K.E.R. and H.W.; investigation, E.J.K.; writing—original draft preparation, E.J.K., G.S.W., H.W., J.W. and K.E.R.; writing—review and editing, E.J.K., G.S.W., H.W., J.W. and K.E.R.; supervision, K.E.R., H.W., G.S.W. and J.W. All authors have read and agreed to the published version of the manuscript.

3.10 Funding

The first author was funded by The Australian Government Research Training Program Scholarship; otherwise, there was no external funding.

3.11 Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Flinders University Social and Behavioural Research Ethics Committee (SBREC) in South Australia (Project number 8634, Approved 15 May 2020).

3.12 Informed Consent Statement

The authors thank the participants of this study for their time and contribution. Informed consent was obtained from all subjects involved in the study.

3.13 Data Availability Statement

Data is not publicly available, however it can be provided by contacting the corresponding author.

3.14 Acknowledgments

The authors thank the participants of this study for their time and contribution.

3.15 Conflicts of Interest

The authors declare no conflict of interest.

4. EVALUATION OF COMMERCIALLY AVAILABLE METHAMPHETAMINE PRESUMPTIVE TESTS FOR SITE CONTAMINATION

This chapter describes the evaluation of presumptive tests or lateral flow immunoassay tests used to detect methamphetamine contamination. This is one method that was found to be commonly used by methamphetamine testing, remediation and validation industry (described in Chapter 3 (Kuhn, Walker, Whiley, et al., 2021). These are inexpensive and quick compared to quantitative laboratory testing; however, prior to this study there was limited knowledge regarding their efficacy and sensitivity.

This manuscript was published during the course of the PhD.

Evaluation of commercially available methamphetamine presumptive tests for site contamination

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4.1 Abstract

Presumptive tests or lateral flow immunoassay testing kits are increasingly being utilised as a fast, portable, cost-effective method to detect an array of analytes, particularly illicit drugs. In Australia, the methamphetamine and decontamination industry regularly use presumptive testing kits to determine whether a property is contaminated. These presumptive test kits advertise a detection limit of 0.5 µg/100 cm^2 and above for methamphetamine. The performance of seven methamphetamine presumptive test brands and their kit components were analysed in this study. Following the kit instructions, each kit was analysed using a ceramic tile that was spiked with a known concentration of methamphetamine. These presumptive test kits were highly sensitive, with positive results also found below the limit of detection. Therefore, if there is a negative result it is likely that there is no methamphetamine present. Those that return a positive result require further quantitative assessment. Thus, the presumptive test kits may detect the presence of methamphetamine that is below the Australian Clandestine Drug Laboratory Remediation Guideline of 0.5 µg/100 cm^2. This indicates these tests might be useful as a screening assessment but should not be relied upon to develop a remediation action plan.

4.2 Introduction

Worldwide, the use of methamphetamine is an issue of increasing concern, with the number of users growing (Armoon et al., 2023; Perez et al., 2022; Pro et al., 2022; Thoi et al., 2022). Both clandestine laboratories used to manufacture methamphetamine, and the smoking of this drug, release vapours that contaminate the surrounding environment, including houses, hotel and motels and cars (Cherney et al., 2006; Martyny et al., 2004; Wright et al., 2016a). These residues deposit on surfaces and can become embedded in porous materials in exposed areas such as carpets, gyprock and furnishings (Bitter, 2016; Martyny et al., 2008; Van Dyke et al., 2009). Research has also found that possessions introduced post-smoking or post-cooking into a contaminated environment will also become contaminated with methamphetamine (Wright et al., 2019). Health effects can arise when the methamphetamine subsequently desorbs from these surfaces and materials, and people are exposed to the methamphetamine - days, months or even years later (Poppendieck et al., 2015; Wright, Kenneally, et al., 2020; Wright, Symons, et al., 2020; Wright et al., 2019). Notably, new residents that are unaware of the history of the property can be exposed to these methamphetamine residues, which can result in adverse health effects (Poppendieck et al., 2015; Thrasher et al., 2009; Wright, Kenneally, et al., 2020; Wright, Symons, et al., 2020). Headaches, itchy, watery eyes, insomnia, respiratory, and behavioural and cognitive issues have been reported in people, including children exposed to methamphetamine contamination (Ciesielski et al., 2020; Salocks, 2009; Thrasher et al., 2009; Wright, Kenneally, et al., 2020).

When there is suspicion that a property is contaminated with methamphetamine, owners engage methamphetamine testing companies to determine the level of contamination. The Australian Clandestine

Drug Laboratory Remediation guidelines have set a health guideline limit in residential settings of 0.5 µg methamphetamine in a 100 cm^2 sample (Australian Crime Commission, 2011). Remediation is required for samples that exceed this contamination value (Australian Crime Commission, 2011). This guideline was developed to educate and ensure a range of stakeholders understood the requirements and expectations involved in remediating a contaminated property in Australia (Australian Crime Commission, 2011). This remediation limit can vary depending on the country and even state or province. For example, in the United States, Washington has a limit of 1.5 µg/100 cm^2; Michigan has a limit of 0.5 µg/100 cm^2; and Connecticut requires anything above 0.1 µg/100 cm^2 as requiring remediation (Granholm & Olszewski, 2007; Hazardous Materials and Waste Management Division, 2003; Kuhn et al., 2019; Rusnak et al., 2006; Washington State Deparment of Health, 2005). Whereas, New Zealand's remediation limit was 0.5 µg/100 cm^2, then a standard limit of 1.5 µg/100 cm^2 was developed, and a limit increase to 15 µg/100 cm^2 is currently being proposed (Kuhn et al., 2019; Ministry of Housing and Urban Development, 2022; Standards New Zealand, 2017).

Currently in Australia, there are no legislative nor regulatory controls for the methamphetamine testing and decontamination industry (Kuhn et al., 2019). This has resulted in no accreditation processes, and a wide range of techniques being used and no standardisation to the practices being used (Kuhn, Walker, Whiley, et al., 2021). One common practice is the use of lateral flow immunoassay testing kits that develop an extra line when methamphetamine is not present in the sampling buffer solution. Lateral Flow Assays (LFA) are a low cost and transportable method of analysis that provides quick results (Koczula & Gallotta, 2016). The LFA technology has been adapted to detect a wide range of analytes including pesticides, microorganisms, metals, toxins, human proteins, and contaminants (Koczula & Gallotta, 2016; Sajid et al., 2015). The methamphetamine LFA tests, also referred to as presumptive tests, advertise that they can detect various different mass thresholds for methamphetamine. In Australia, the LFA tests sold and used, claim a threshold or detection limit of 0.5 µg methamphetamine in a sample, however, there has been no independent testing undertaken to validate these claims. This study aimed to determine the efficacy and accuracy of these tests.

4.3 Materials and method

4.3.1 Ordering test kits

Company websites that advertised and sold methamphetamine-specific presumptive test kits in Australia were identified and six kits were ordered from the suppliers' websites. There was also one brand of test kits that were donated by the supplier when they heard about the study. Although seven methamphetamine testing kits came from separate websites and suppliers, the testing kits appeared to be from three manufacturers. This inference could not be verified, however each test kit appeared visually distinctive.

This could indicate that tests were purchased in bulk and rebranded by the suppliers which increased the sample size of the test kit analysis. Notwithstanding, the test kit brands will be referred to as Brands 1 to 7.

4.3.2 Surface preparation

To ensure the performance of the presumptive test kits could be analysed, a non-porous surface was selected and cleaned (Madireddy et al., 2013; Serrano et al., 2012). Commercially available and commonly used, ultra white gloss ceramic bathroom tiles (Johnson Tiles, China) were purchased. All tiles were cleaned with 70% ethanol solution (Chem-Supply, Australia), then cleaned through a rinse cycle in the laboratory dishwasher (Miele®, Germany) at 15 °C for four minutes.

4.3.3 Methamphetamine standard preparation

Analytical grade methamphetamine (Cayman Chemical, United States) was used for all tests. The methamphetamine was suspended in methanol (Chem-Supply, Australia) and then prepared into varying concentrations of 0.18, 0.24, 0.6, and 0.7 µg per 100 µL. This was confirmed by quantitative liquid chromatography with tandem mass spectrometry (LC-MS/MS) analysis (ACS Laboratories (Australia), Victoria), that followed the National Institute for Occupational Safety & Health (NIOSH) standard 9111 (NIOSH, 2011c).

4.3.4 Experimental method

Methamphetamine of each concentration was deposited on the surface of a ceramic tile in individual droplets using a micropipette. These were prepared in triplicate (three ceramic tiles). Each tile was left for 10 min to allow the methanol to volatilise and the methamphetamine deposits to dry on the surface.

Individual test kit instructions were followed and notably, each of them differed. However, as a generalisation, swabs were removed from their sterile packaging and dipped into the liquid buffer provided. The surface was then swabbed within a 100 cm^2 template square, following a zig zag motion on the tile, from left to right, then up and down, and left to right again, as per the Australian Voluntary Code of Practice (Wright, 2019). The swab was returned to the buffer where it was agitated within the bottle for several seconds and then removed. The buffer bottle was shaken for 20–30 s to homogenise the liquid, and then 3–4 drops were administered to the cassette with 2–5 s intervals. The length of time required to wait for red lines to appear ranged from 30 s to 5 min. Results were read after 5 min, but before 10 min to ensure the readings were still valid. All presumptive test kits had the same method of displaying the result. With the exception of one brand, all of the test kit cartridges gave a positive result for one line furthest away from the well, two lines was a negative result, and one line closest to the well was an invalid result. The other brand had similar results for the single and double lines, but different positioning away from the well. This process was repeated for all of the methamphetamine standards, and each test kit was repeated in triplicate.

For the analytical positive control, wipes (Teri Wipers®, United States of America) were dampened with 3 mL methanol. The aim was to deposit a known concentration on to the ceramic tile with methanol, which would evaporate and the known mass would remain. This was to allow for a direct comparison with the Australian guideline of 0.5 µg/100 cm^2. Thus, 100 µL of each methamphetamine concentration was aliquoted onto a ceramic tile, left for 10 min to dry, and then wipe sampled using the standard procedure described above (the Australian Voluntary Code of Practice (Wright, 2019)). These same methamphetamine concentrations were also put directly by micropipette onto a wipe as a positive control. The negative controls of methanol only, and the positive controls were sent to ACS Laboratories (Australia). Quantitative liquid Chromatography with tandem mass spectrometry (LC-MS/MS) analysis was used following the National Institute for Occupational Safety & Health (NIOSH) standard 9111 (NIOSH, 2011c).

4.4 Results

For the purposes of this research "accurate" means either that the test returned a negative result when there was less than 0.5 µg/100 cm^2 methamphetamine added to the tile, or returned a positive result when there was more than 0.5 µg/100 cm^2 methamphetamine added to the tile. Overall, of the 72 test kits, 59% returned an accurate result.

The test kits from Brand 3 were two months past their expiry date when the experiment was conducted. These expired test kits detected 0.7 µg/100 cm^2 (an accurate result), but also returned an inaccurate result with 2/3 positive results for 0.18 µg/100 cm^2 (which is considered to be below the detection limit). The results for this brand have been excluded from the rest of the results and most of the discussion.

Notably, 26 tests returned a positive result when there was methamphetamine present, but with less 0.5 µg/100 cm^2 methamphetamine added to the tile, despite 0.5 µg/100 cm^2 being their advertised limit of detection. This was for both 0.18 µg and 0.24 µg/100 cm^2 (Table 2), with Brands 1, 4 and 5 inaccurately giving a positive result in all of the tests.

Table 2. Results from the presumptive tests for each brand (✓ indicates an accurate result, O indicates an incorrect result below the limit of detection, X indicates a false negative result).

Concentration (µg/100 cm^2)	Brand 1	Brand 2	Brand 3[a]	Brand 4	Brand 5	Brand 6	Brand 7
0.7	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
0.6	✓✓✓	[b]	[b]	✓✓ X	✓✓✓	[b]	✓✓ X
0.5 µg/100 cm² – stated limit of detection for all kits							
0.24	O O O	✓✓✓	✓✓✓	O O O	O O O	✓✓✓	[b]
0.18	O O O	O O ✓	O O ✓	O O O	O O O	O O O	O O O
0	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓

Most kits were tested three times for each concentration.

[a] Brand 3 was out of date and so results should be interpreted with caution.

[b] Indicates that this test was not performed on that brand.

Two of the tests returned a negative result when there was more than 0.5 µg/100 cm^2 methamphetamine added to the tile (Brand 4 and Brand 7). For both of these brands, the negative result was one out of three tests, with the other two tests being positive. All of the test kits accurately produced a negative result for the 0 µg methamphetamine/100 cm^2 (Table 2). These results indicate that the test kits are more sensitive than advertised, with many tests showing methamphetamine contamination at levels below their stated limit of detection of 0.5 µg/100 cm^2. This contrasts with the 100% accuracy for all of the negative tests, which were correctly identified as negative.

4.5 Discussion

Products that are manufactured and mass produced inevitably produce some with imperfections and others that malfunction (Pedgley et al., 2018). Quality control and product testing is therefore an imperative step in the manufacturing process (Judi et al., 2011). It has been argued that it should be the responsibility of the manufacturer to provide the statistical quality control data to the supplier (Ueki, 2016; Urbaniak & Zimon, 2022). This information should then be passed onto the consumer to ensure that they understand the risks or limitations of the product and are making a sound decision when they select the product.

For the purposes of this study, an accurate result was when the test kit correctly identified the presence or absence of methamphetamine corresponding with the concentration tested. Hence, a negative result was any incorrect result according to the concentration tested. This includes positive results below the limit of detection.

However, when the brands we purchased have supplied customers with quality control data, the information is stated as positive and negative percentages. These statements can be confusing or misleading, as it has been established in this study that test kits can have a positive result for methamphetamine below the advertised limit of detection. Thus, it is not clear whether the quality control data actually represent zero methamphetamine or below 0.5 µg. Brand 3 stated the accuracy of the test as 93.7% positive and 98.2% negative, while Brand 1, 5 and 6 all claimed to have 97.45% positive and 99.38% negative test results (Table 3). The remaining brands did not provide the quality control data to the consumer.

Table 3. The quality control data provided to customers in the methamphetamine presumptive test kits.

Brand	Negative (%)	Positive (%)
1	99.38	97.45
2	N/A [a]	N/A [a]
3	98.2	93.7
4	N/A [a]	N/A [a]
5	99.38	97.45
6	99.38	97.45
7	N/A [a]	N/A [a]

[a] N/A means that there were no quality control data provided

Based on the results of this study, these presumptive tests are more sensitive than reported and produce a high number of positives for concentrations below their stated limit of detection. This has serious public health implications since it would increase the financial burden, time spent and stress for both those residing within the property and those that own it. It is therefore clear that a positive result from a lateral flow test should be considered only as a prompt for further quantitative testing, not as a definitive result. Decisions based on the presumptive tests alone is a reported concern (Kuhn, Walker, Whiley, et al., 2021), especially for illicit drugs (D'Nicuola et al., 1992; Kricka, 2000; Marin et al., 2016; Pesce et al., 2010; Saitman et al., 2014). If not used appropriately, these tests can provide the opportunity and financial incentive for businesses to offer remediation services to those that do not require it.

According to the New Zealand Standard 8510:2017 (NZS), all methamphetamine testing kits must be validated by an organisation that is accredited by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) 17025 (Standards New Zealand, 2017). Any validation studies must be publicly available and listed on their website. Test kits should also be re-analysed at 12 monthly intervals or if there is a change in the standardised limit of methamphetamine, or any performance issues or risk of being compromised (Standards New Zealand, 2017). The Institute of Environmental Science and Research Limited (ESR) was contracted to independently test and analyse a particular brand of presumptive tests in line with the NZS (Larsen, 2018). According to the NZS, the methamphetamine contamination limit is 1.5 μg/100 cm^2, therefore the test kits passed the Standard's published criterion (Larsen, 2018). These kits are sold and distributed in locations with a lower accepted limit, thus they were tested for 1.5 μg/100 cm^2, but not the 0.5 μg/100 cm^2 as per the Australian Guidelines.

Ciesielski et al. (2020) found that using methamphetamine test kits that were developed by Health Effects Laboratory Division at the Centers for Disease Control and Prevention's National Institute for Occupational Safety and Health, had a high degree of specificity and sensitivity (Ciesielski et al., 2020). These kits were able to detect methamphetamine at a level 25 times lower than their limit of detection with 95.08% specificity and 88.57% sensitivity. Reassuringly, in our testing only 0.07% of all tests failed to detect methamphetamine when it was present above the limit of detection. However, the significant number of tests returning positive results below the stated limit of detection should reinforce the idea that this is a prompt for further quantitative testing and should not be considered an accurate result.

The tests ranged in price from AU$13 to AU$18 per sample. The test kits came with various components, and a number of kits were missing vital components (Table 4). The testing kits we purchased are advertised to the general public, who may not have any prior knowledge or understanding of methamphetamine contamination, so it is important that the components are all there, and that the instructions are clear.

Table 4. The components that were included in the kits that were tested in this study

	Price per Test AU$	Transit to Adelaide	Swabs	Test	Buffer	Gloves	Template	Glove Change	Blank Test	Quality Control
Brand 1	17	7 days	✓	✓	✓		✓	✓	✓	✓
Brand 2	N/A	N/A	✓	✓	✓	✓				
Brand 3	13	7 days	✓	✓	✓	✓	✓			✓
Brand 4	18	2 days	✓	✓	✓	✓				
Brand 5	15	15 days	✓	✓	✓		✓	✓	✓	✓
Brand 6	15	16 days	✓	✓	✓		✓	✓	✓	✓
Brand 7	18	7 days	✓	✓	✓		✓			

Each of the kits were missing at least one component that could affect the outcome of the test. Missing components all differed. Several brands recommended changing gloves between tests but did not provide any, the swabbing area was always based on 100 cm^2 and some suppliers did not provide a template. A number of kits did not contain recommendations for consumers to conduct their own blank test.

4.6 Recommendations

The outcome of this study demonstrates that the presumptive methamphetamine testing kits are simple to use but are prone to inaccurate results as concentrations decrease. It seems clear that the accuracy of a test is impaired over time. The expired test kits from this study were only two months out of date but yielded significantly more inaccurate results compared with the other test kits. However, it should be noted that it is possible that this might not be the result of the kit, but simply due to being out of date.

Due to the high number of positives below the limit of detection, these tests should be used as a screening tool, but this should always be followed with quantitative analysis prior to the development of a remediation action plan. This is supported in the literature (Wright, 2019). There have been reports that some occupational hygienists are using presumptive testing methods when validating that a contaminated property has been adequately remediated (Kuhn, Walker, Whiley, et al., 2021). This is an unacceptable practice due to the accuracy and validity of these presumptive test kits. Quantitative wipe samples that are sent to a National Association of Testing Authorities (NATA) accredited laboratory should be the only tests accepted and recognised (Wright, 2019).

4.7 Limitations

It is understood that the methamphetamine found within residential properties is not an analytical grade methamphetamine, as was used in this study. It was important to use methamphetamine with minimal impurities to ensure those unknown substances were not producing inaccurate results. Future research could explore the impact of these impurities on the reliability of the test results. In addition, there are other factors not tested for in this study that may affect the accuracy of the results provided by presumptive test kits. For example, these kits have been designed for use by commercial testing, cleaning companies and also members of the public. Consequently, the use of these kits by inexperienced persons may add additional variation to the results compared with those presented in this study, where the testing was performed by laboratory trained researchers. Also, the glazed ceramic tiles used in this study are non-porous and easily cleaned. Variations in recovery from different surfaces would impact the accuracy of the results provided by the presumptive test kits (Abdullah & Miskelly, 2010; Madireddy et al., 2013; Martyny et al., 2008; Serrano et al., 2012).

4.8 Conclusion

The low cost of presumptive kits for methamphetamine testing means that they provide a valuable tool for initial screening. Our study indicates that the tests did not detect methamphetamine when it was not present but did detect low levels, below the detection limit of 0.5 µg/100 cm^2, which might cause significant stress and anxiety. It is therefore recommended that any positive result be confirmed with quantitative testing and that no decisions about remediation, nor remediation success, are made based on positive presumptive test kit results. These tests should be used only as a preliminary screening tool and the results externally validated. It is recommended that mandatory quantitative assessment after screening returns a positive result be required. This will not only improve testing and decontamination practices, but also increase public trust and perception of the industry.

4.9 Disclosure statement

No potential conflict of interest was reported by the author(s).

4.10 Funding

The first author was funded by The Australian Government Research Training Program Scholarship; otherwise, there was no external funding.

5. SPATIAL DISTRIBUTION OF METHAMPHETAMINE ON WALLS PRE- AND POST-REMEDIATION

This chapter describes an approach to determine the spatial distribution of methamphetamine contamination inside a residential property both before and after remediation. The study assessed the methamphetamine on the internal walls of a property. The study found significant variation in methamphetamine concentrations depending on where the sample was taken. The findings of this work can be used to inform industry practices about the appropriate sampling locations and on uncertainties with selective sampling within properties to ensure proper evaluation is undertaken. This study also found that in this particular case study, remediation did not reduce the level of methamphetamine contamination, which supports anecdotal evidence about the efficacy of remediation processes and the potential movement of contamination throughout a property.

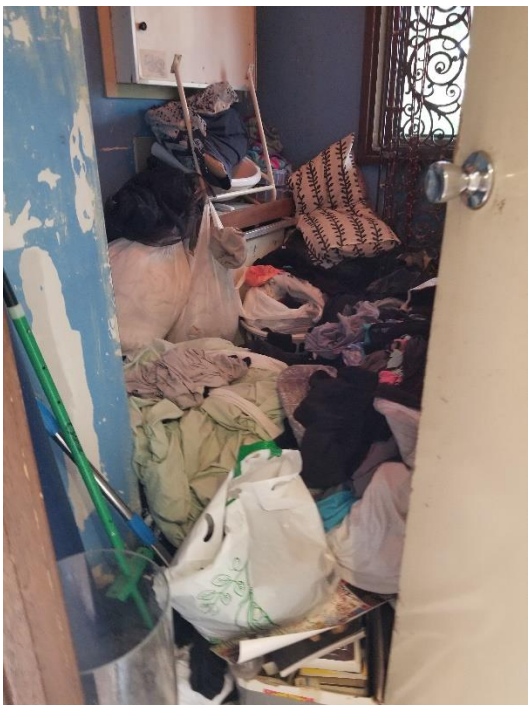
5.1 Method

5.1.1 Background

The title of the residential property used in this case study had a mortgage held by the resident, who passed away. Relatives moved into the house and had not continued with the mortgage repayments, and the bank repossessed the property (Merc Property, 2022). The repossession process was being managed by a company that specialised in property recovery, who contacted the author of this thesis and offered access to the contaminated property for research purposes. The house had been quantitatively tested and confirmed as being contaminated with methamphetamine by a commercial testing company.

5.1.2 Property access

All items within the property remained the possession of the residents, and only the structural components were owned by the bank. Therefore, only non-destructive wipe sampling of the property structure was permitted. Notably, the house would be considered deliberate hoarding (defined as “A lifestyle choice whereby there is a failure to remove household waste, rubbish and other items”) (Health Protection Programs, 2013a) as every room held a significant quantity of accumulated furniture, clothing, objects, and rubbish. Some rooms were inaccessible due to items blocking the entry way and floor space (Figure 4). The residents also appeared to be undertaking renovations or alterations in several rooms, which were all at different stages. The lounge room, bedroom, kitchen, and bathroom had wall surface finishes that were customised but unfinished. This is of note as these impeded access to some wall spaces.

(a)  (b) 

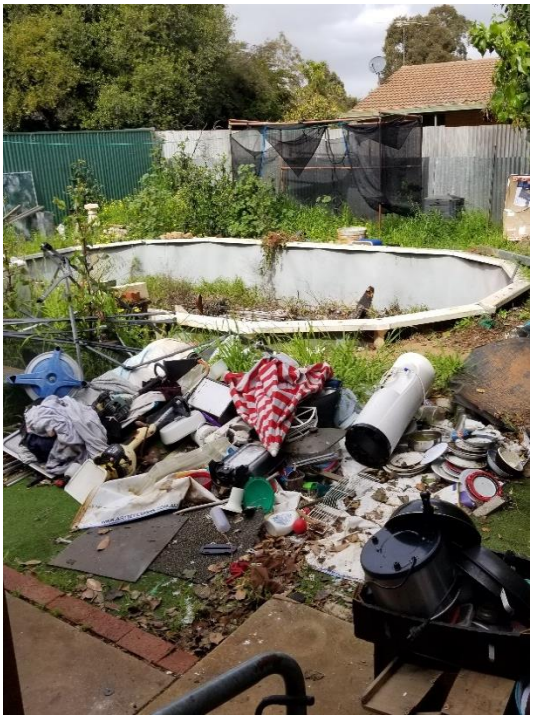
(c)  (d) 

Figure 4: Photos of the property taken on arrival prior to sampling (a) bedroom 2, (b) laundry, (c) lounge room, and (d) the backyard area and the swimming pool

5.1.3 Sampling location

As noted above, accessing specific locations to sample was challenging and was dependent on whether walls were accessible. Sampling was undertaken on one wall in the lounge room and one wall in the kitchen (Figure 5).

Figure 5: A schematic of the house sampling plan with red dots indicating the sampling locations in the lounge room and the kitchen. The air conditioner (a/c) in the lounge room and the missing exhaust fan in the kitchen is also shown

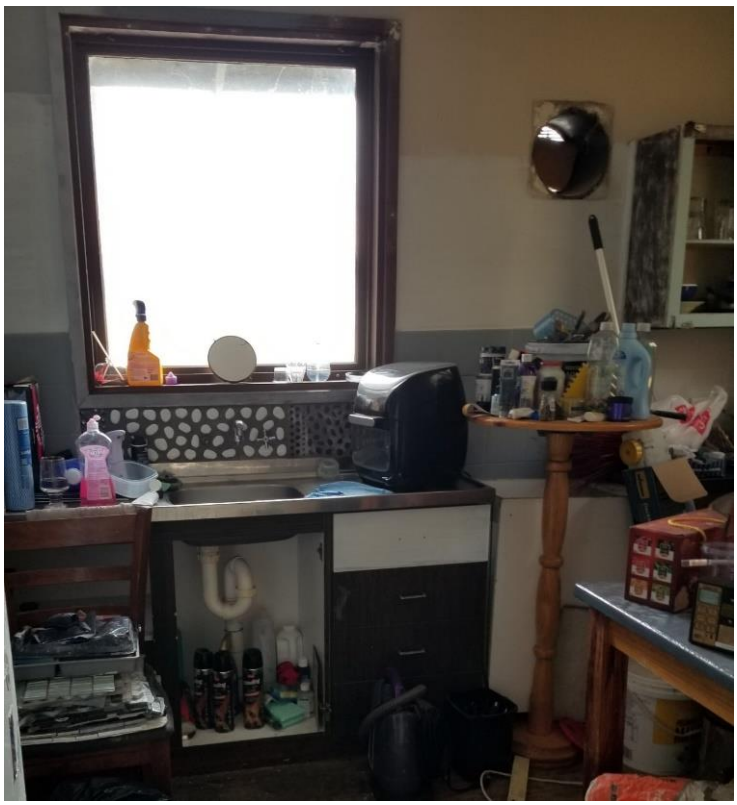


Figure 6: The kitchen wall (upper right corner) that was sampled. The built in cupboard and exhaust fan hole in the wall (both upper right) can also be seen

Figure 7: The lounge room wall (above and behind the washing basket) that was sampled. The sliding door (left) and the other door handle (right) can also be seen

5.1.4 Sampling technique

Terry Wipers® sheets were cut into four, folded into quarters, and placed inside a 50 mL centrifuge tube with 3 mL methanol (Scharlab, Spain) (NIOSH, 2011c). A piece of thick polyethylene plastic sheeting had six 100 cm^2 squares cut out and labelled A, B, C, D, E and F (hereafter "template" (Figure 8). Each sample was taken wearing double nitrile gloves and the sampling method from the Australian Voluntary Code of Practice was followed (Wright, 2019). In summary, the wipe was removed from the tube with one hand, wiped up and down, left to right within the template square, folded then wiped from left to right, top to bottom, and folded again to wipe up and down, left to right. The wipe was placed back into the tube and enclosed with the lid. This process was repeated for samples A to F for each wall. The samples were transported to Flinders University and stored securely in the Environmental Health laboratory.

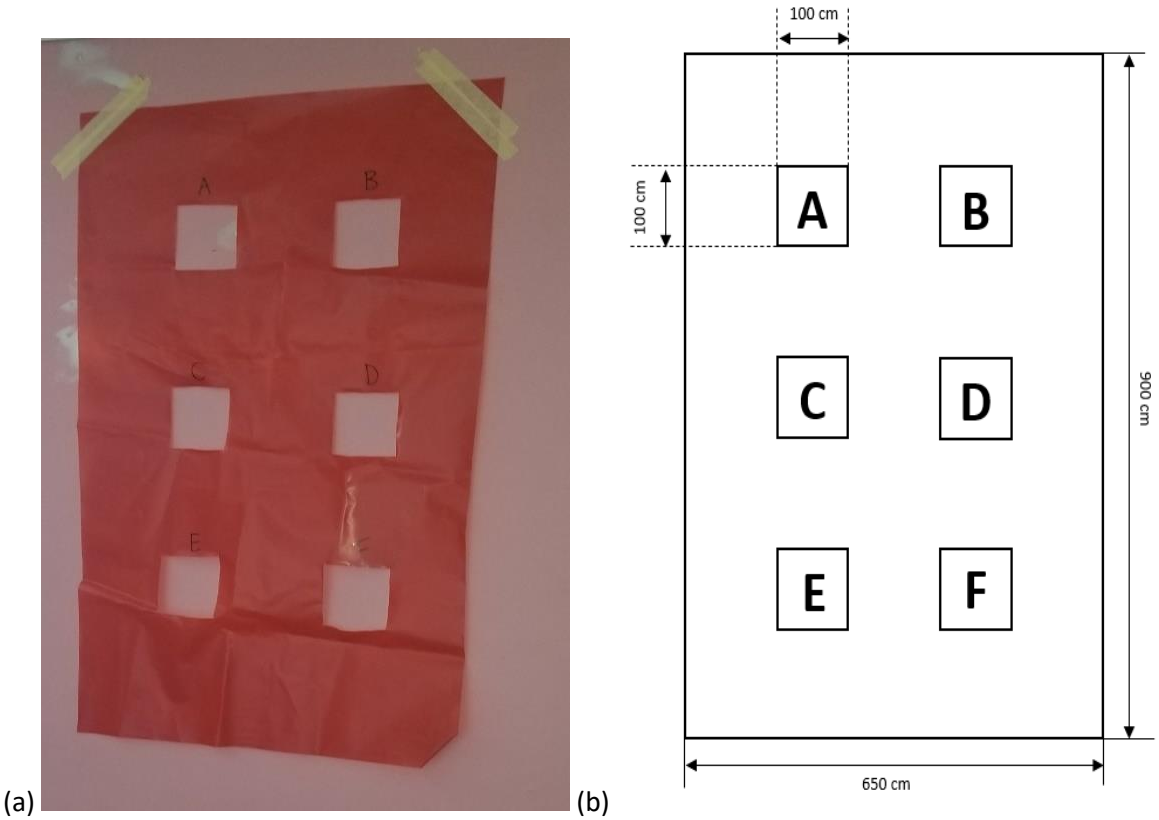


Figure 8: (a) The plastic sheeting template used for wipe sampling the property walls; (b) the A to F position order that the samples were collected

5.1.5 Post remediation sampling

A commercial remediation company was employed by the property management company to undertake remediation of the property (Merc Property, 2022). Once remediation was complete, the property manager provided access to the house to collect post remediation samples. The sampling technique outlined above was used, with the exception that the template was moved to the right of the original sampling locations to ensure sampling was taken from "fresh" wall surfaces.

5.1.6 Wipe sample analysis

To quantify the methamphetamine present on the wipe samples, a Liquid Chromatography Mass Spectrometry (LCMS) was used with a Thermo Scientific™ Vanquish™ Horizon with an ISQ™ EC single quadrupole mass spectrometer (Massachusetts, United States). Separation was performed using an Ultra High Performance Liquid Chromatography (UHPLC) column with particle size 1.7 µm, 100 mm length, and 2.1 mm diameter ((Phenomenix®, Kinetex® C18), California, United States).

At the start of every LCMS sample run, two system blanks and two matrix blanks were prepared. The system blanks had no injection volume, but would use the mobile phases, and the matrix blanks were negative controls of methanol only.

The National Institute for Occupational Safety & Health (NIOSH) 9111 method for Methamphetamine on Wipes by Liquid Chromatography-Mass Spectrometry was used. This method forms the basis for the proficiency tests for methamphetamine on wipes that is conducted by the National Measurement Institute in Australia (National Measurement Institute, 2023). This method was developed for the detection of methamphetamine on wipe samples using liquid chromatography-mass spectrometry (NIOSH, 2011c). Most of the NIOSH 9111 instructions were followed, however there were some steps that were adapted.

The internal standard prepared was a labelled deuterated methamphetamine-D_9 (Cayman Chemical, Michigan, United States) at a 100 µg/mL concentration, and the spiking solutions were prepared at 200 µg/mL and 20 µg/mL. The desorption solution was 0.1 M sulfuric acid (Sigma Aldrich, Missouri, United States) with deionised water (Milli-Q®, Massachusetts, United States). Mobile phase A was 0.1% acetic acid (Sigma Aldrich, Missouri, United States), 5% acetonitrile (Honeywell, North Carolina, United States) in deionised water. Mobile phase B was 0.1% acetic acid, 95% acetonitrile in deionised water. Both solutions were prepared and then degassed using a sonicator ((CooperVision, model 895), South Australia, Australia).

The spiking solutions were used to prepare calibration standards according to the NIOSH 9111 method (Table 5). Standards 1 to 8 were analysed at the start of every sample run and the wall samples followed. For each wipe sample in a 50 mL tube, 50 µL of the internal standard and 30 mL of the desorption solution was added as shown in Table 5. The tube was placed on a rotary mixer ((Ratek, model R5M6), Victoria,

Australia) at 60 rpm for one hour. Using a plastic syringe, 1 mL of the sample was filtered through a 0.22 µm nylon filter (Membrane Solutions®, Washington, United States) into a 2 mL glass autosampler vial.

The column temperature was held at 40 °C, the collision-induced dissociation was at 30 V, and the overall run time was 25 min. The gradient started with 100% of mobile phase B at a flow rate of 0.5 mL/min and was held for 1 min. Mobile phase B decreased within 9 min, and mobile phase A increased to 100% at 10 min and held for 5 min. Mobile phase B was restored to 100% within 2 min and was held for the remaining 8 min. The Collison-Induced Dissociation (CID) was set at 40 for the mass spectrometer. An extracted ion chromatogram was generated for ions 91, 119, and 150 m/z which enabled both consistency and verification for methamphetamine.

Each LCMS runs were comprised of the eight calibration standards (Table 5), and the pre-remediation and post remediation sample wipes. The house samples were analysed in duplicate in a sample run, and then the duplicates were repeated. Thus, each house sample was analysed by the LCMS four times, both within a sample run and between sample runs.

There was also extensive method development to reach the decision to use the NIOSH 9111 methodology. These steps and results can be found in Appendix D.

Table 5: Spiking schedule for calibration standards (NIOSH, 2011c)

	Volume (µL) of Spiking solution				
Standard number	200 µg/mL solution	20 µg/mL solution	Internal standard (µL)	Desorption solution (mL)	Final concentration (µg/sample)
1	500		50	30	100
2	100		50	30	20
3	25		50	30	5
4	5		50	30	1
5		25	50	30	0.5
6		5	50	30	0.1
7		2.5	50	30	0.05
8		1.2	50	30	0.024

5.2 Results

5.2.1 Spatial distribution

The samples from both rooms were analysed for spatial distribution based on where the wipe was taken from. The samples were ordered as shown (Figure 8), as such the results are displayed in the same way. Coloured "heat maps" were created using wipe sample concentration averages, which provides a visual representation of the variation of methamphetamine concentration found on each wall (Figures 9 and 10).

5.2.1.1 Lounge room

All samples collected from the lounge room, both pre and post remediation, were above the recommended "required remediation threshold" of 0.5 µg methamphetamine per 100 cm^2 (Australian Crime Commission, 2011). Interestingly, instead of decreasing, the post remediation samples showed that there was an increase in methamphetamine detected (Figure 9b). This increase ranged from 3.7 times higher for position (E), to 19.7 times higher for position (C) when compared to the pre-remediation counterpart samples (Figure 9a).

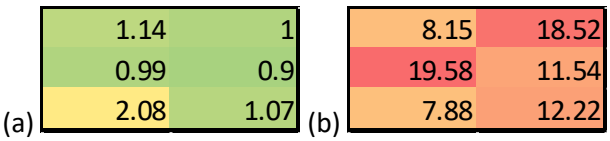


Figure 9: The methamphetamine concentrations for the Lounge Room wipe samples (a) the pre-remediation heat map; (b) the post remediation heat map

5.2.1.2 Kitchen

The pre-remediation kitchen wall samples were also above the "required remediation threshold" of 0.5 µg methamphetamine per 100 cm^2 (Australian Crime Commission, 2011). The kitchen wall had decreased concentrations for position A and B, but comparable result for position C (Figure 10).

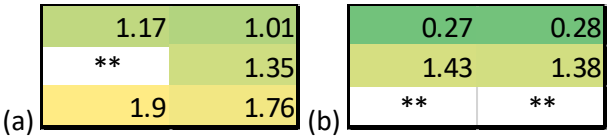


Figure 10: The methamphetamine concentrations for the Kitchen wipe samples (a) the pre-remediation heat map; (b) the post remediation heat map

** Note that the sampling was conducted at the top of the wall and there was a cupboard fixed to the wall meaning not all locations could be sampled.

It is important to note that these are not replicates taken in the identical location on the wall, but they were sampled next to the initial location. This was to determine if remediation had been conducted correctly and if a lower quantity was detected that was not due to removal in the initial sampling.

5.2.2 Contamination based on the room

Statistical analysis was performed on the data to determine if there was a difference between the level of contamination found in the lounge room compared to the kitchen. The non-parametric test, Mann-Whitney U test was conducted on each room separately. For the lounge room, there was a value of $P<0.001$, which indicates there was a statistical difference between samples. However, it is clearly demonstrated that the level of contamination increased post remediation in the lounge room (Figure 11). The kitchen samples were also analysed using the Mann-Whitney U test with a *P*-Value of 0.002, which also indicated that there was a statistical difference between samples (Figure 12).

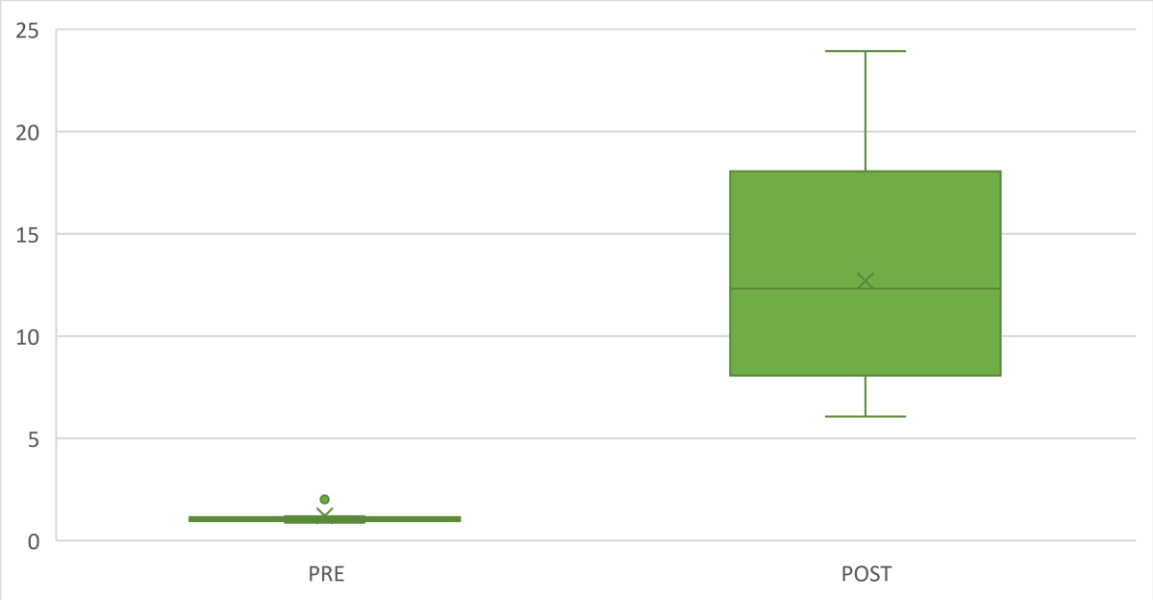


Figure 11: A comparison of the pre and post remediation methamphetamine levels in the lounge room, n=60, and P-Value of <0.001

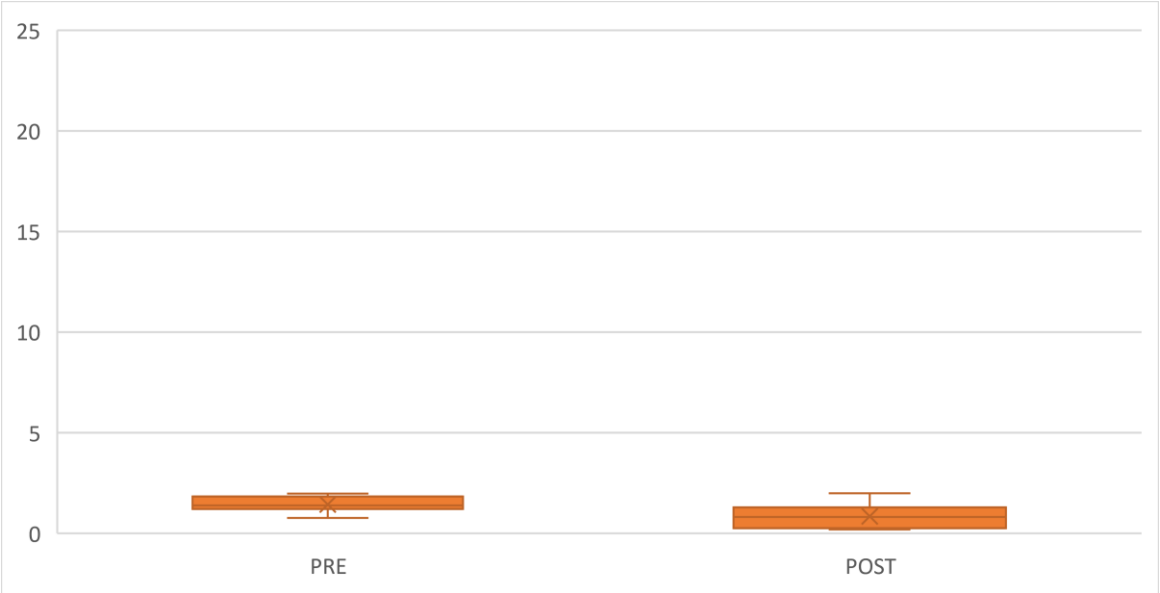


Figure 12: A comparison of the pre and post remediation methamphetamine levels in the kitchen, n=44, and P-Value of 0.002

5.2.3 Contamination pre and post remediation

Statistical analysis was performed on the data to determine if there was a difference between the level of contamination found pre and post remediation for both the lounge room and kitchen. The non-parametric test, Mann-Whitney U test was conducted for the samples collected before remediation and another test for those taken after. For the pre-remediation samples, there was a significance figure of 0.014, which indicated that there was a statistical difference between samples (Figure 13). The post remediation samples were also analysed using a Mann-Whitney U test, which resulted in a *P*-Value of <0.001 (Figure 14).

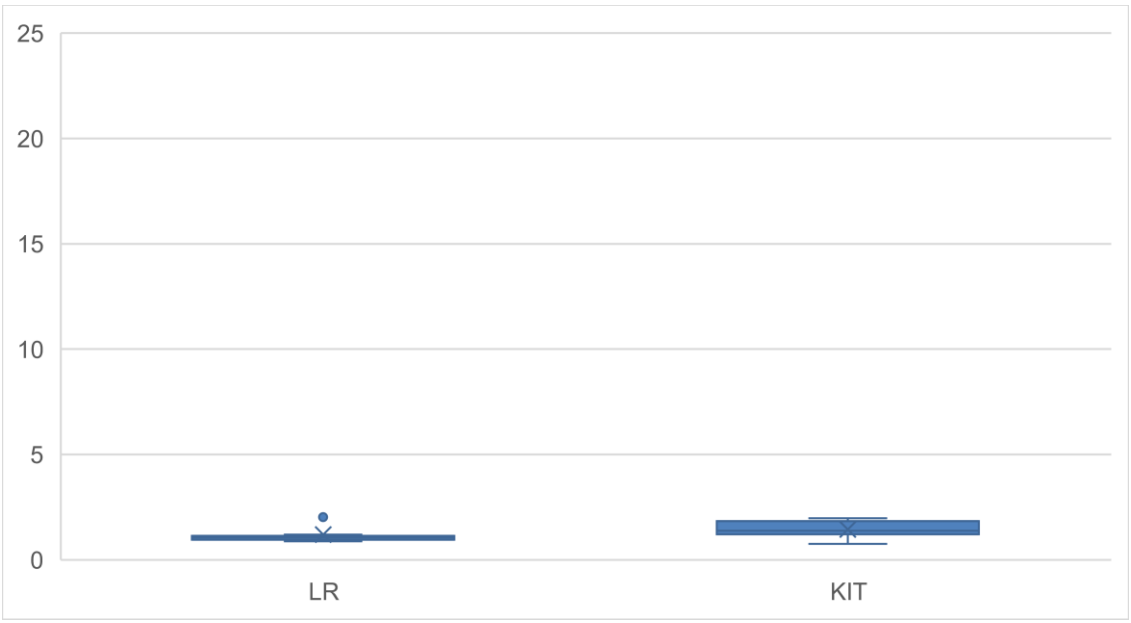


Figure 13: A comparison of the pre-remediation contamination levels in both the lounge room (LR) and the kitchen (KIT), n=50, and P-Value of 0.014

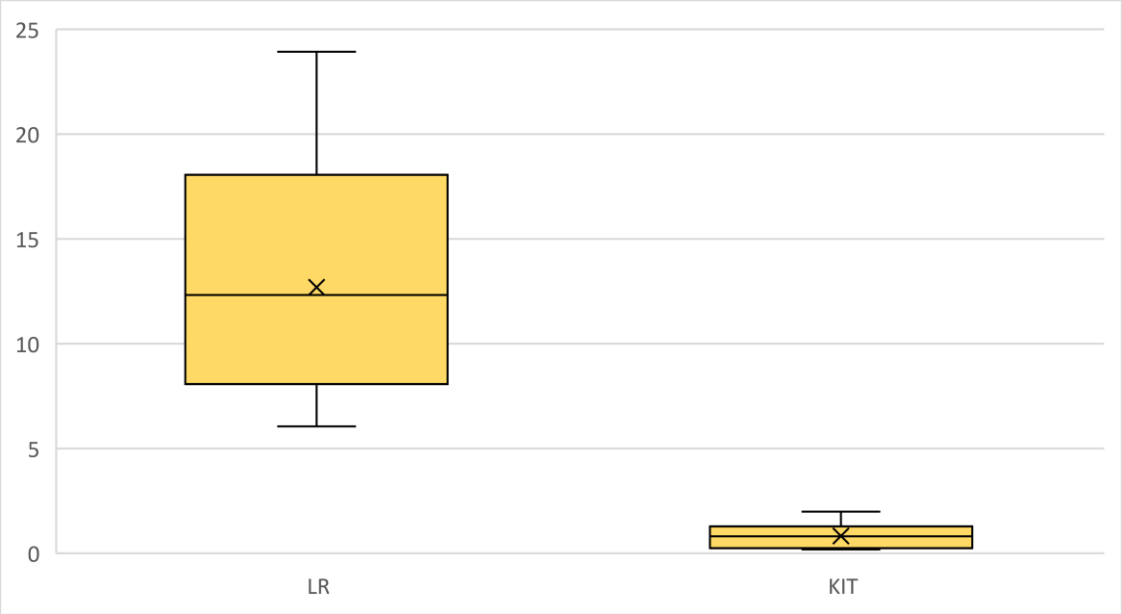


Figure 14: A comparison of the post remediation contamination levels in both the lounge room (LR) and the kitchen (KIT), n=54, and P-Value of <0.001

5.3 Discussion

5.3.1 Variation of sampling positions

The results of these wall samples demonstrate that the wipe sample location can have a high level of variability which would consequently have a significant impact on determining the risk to health, and whether remediation was needed. The Clandestine Drug Laboratory Remediation Guidelines in Australia states that at least five samples should be taken from inside a building and any room that a child inhabits, under the age of 16 (Australian Crime Commission, 2011). Given these general guidelines, commercial testing companies follow these recommendations and typically rely on one room sample to base their decisions about the level of contamination, a remediation action plan and validating the work completed. Thus, the variability over an individual wall is important to understand as it can impact the outcome of the habitability of the home.

Many factors could cause the disparity between the results of the sample positions originating from the same wall. For example, the positioning of furniture such as a cupboard that could block the wall, or a lounge suite that would seat people closer to the wall. Alternatively, different types of paint have been found to retain or encapsulate methamphetamine. A recent study reported 50-96% removal of methamphetamine and this was based on wipe samples before and after remediation (Gao et al., 2023). However, Serrano et al. (2012) investigated the effectiveness of an oil-based enamel, an oil-based primer, and a latex paint. The oil-based paints effectively (100%) encapsulated the methamphetamine on drywall, and the latex paint resulted in 83% with 5 µg/100 cm^2 remaining (Serrano et al., 2012). Yet, the analysis of residual methamphetamine on drywall found that wipe samples removed 37% and 58% remained within the paint and paper layers (Serrano et al., 2012). Given the property from this study was being renovated in a personalised fashion and that the type of paint was not determined, this might be a possible explanation for the variation found in the methamphetamine detected in each sample position.

Additionally, research with a simulated cook reported that airborne methamphetamine can be detected in a room separate from the manufacturing area up to 24 hours after (Van Dyke et al., 2009). Interestingly, another study from the same research group found that as the distance from the smoking area increased, there was no pattern or consistency for the methamphetamine concentration detected (Martyny et al., 2008). Thus, there are other environmental factors like air movement might cause the differential deposition. Within the context of this study, there was a wall air conditioner in the lounge room and a hole for an exhaust fan in the kitchen (Figure 5). These factors could cause both air movement and climatic variation that would impact the mobility and therefore exposure to methamphetamine.

5.3.2 Decontamination

The increase in the level of methamphetamine seen between the lounge samples before and after remediation are significant. The property manager has not disclosed the method used to decontaminate the house (if known) thus the chemicals or techniques cannot be analysed. The results do indicate that there has either been cross contamination of re-used cleaning solutions, or the technicians have employed a method that has increased the mobility of methamphetamine and it has permeated through the wall. Poppendieck et al. (2015) demonstrated that methamphetamine could desorb from wallboard with the increase in relative humidity from 27% to 49%.

This highlights a substantial challenge for technicians in the methamphetamine testing, remediation and validation industry, or those that engage with them. The National Clandestine Drug Laboratory Remediation Guidelines in Australia state that at least five wipes are to be taken within a house, and from any room inhabited by a child younger than 16 years of age (Australian Crime Commission, 2011). When these recommendations are practically applied to a house, they become too broad for adequate assessment. Industry members were surveyed in a previous study on their sampling location within a contaminated bedroom (Kuhn, Walker, Whiley, et al., 2021) (Chapter 3). This question provided an open text box for participants to answer in, and there was a high level of variation in the responses. Sampling locations included the ceiling, door, fan, light switch and bed head (Kuhn, Walker, Whiley, et al., 2021). This also emphasises the flaws in a field composite sample approach that would only provide an averaged value of contamination, whereas a laboratory composite can still provide individual sample results if required (Wright, 2019).

Anecdotally, another property managed by the same company had similar issues with inconsistent concentration values. The house was tested, the samples were sent for laboratory analysis for Detailed Forensic Assessment prior to the remediation and then post validation tests were performed by three separate companies (Table 6 and Figure 15). This serves as an example of the variable results that Environmental Health Officers, Police, private businesses and members of the public face when engaging with the methamphetamine decontamination industry. Without knowing the location of where the samples were taken, there is no way of knowing who is ‘accurate’. This also emphasises the need for standardisation with regards to location, technique, chemicals, and equipment (Kuhn et al., 2019).

Table 6: Methamphetamine wipe concentration results received from three different testing companies (Merc Property, 2023). The results in red are above the National Clandestine Drug Laboratory Remediation Guidelines in Australia recommend *α* level of 0.5 µg/100 cm^2 and the results in black are below (Australian Crime Commission, 2011). The values in orange are results that are slightly above or below 0.5 and would be within the margin of error.

Room	Detailed Forensic Assessment	Post Validation Test		
		Tester 1	Tester 2	Tester 3
Garage	2.9	0.35	0.04	0.08
Bedroom 1	8.9	3.3	1.9	0.45
Bedroom 2	2	0.73	0.18	0.02
Bedroom 3	19	0.86	0.63	0.04
Meals	17	0.1	3.2	0.7
Kitchen	32	15	0.04	0.7
Lounge	1	9.6	0.47	0.7
Hallway	13	10	5	0.53
Toilet	8.9	3		
Bathroom	14	0.26	0.7	0.06
WIR	19	8.1	0.29	0.15
Laundry	2.9	0.71	0.02	0.08

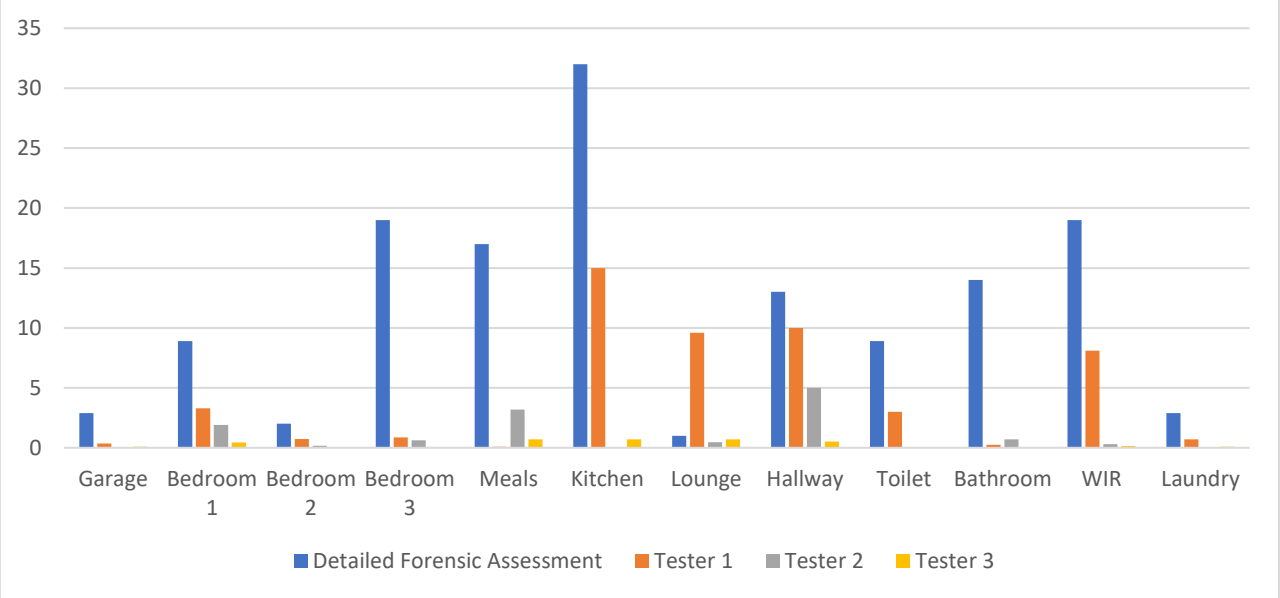


Figure 15: Graph of methamphetamine wipe concentration results received from three different testing companies (same data as Table 6)

5.4 Recommendations

This study shows that there is significant spatial variation in the levels of methamphetamine detected on walls from the distribution, the contamination based on the room, and the levels pre and post remediation. Each of the comparisons observed a statistical difference between them which confirms the need for a different sampling strategy such as multiple samples or sampling from a larger area and then adjusting it to find the average of 100 cm^2. Both of these approaches would provide a more accurate representation of the levels present for the wall or surface. This study also confirms that remediation of methamphetamine is difficult, and that the current approaches are not necessarily successful, even if undertaken by a reputable cleaner. This confirms the need for stringent post remediation testing, which should be done by a different analyst to reduce any conflicts of interest or uncertainties from a public perspective (Kuhn, Walker, Whiley, et al., 2021).

In a literature search, there were only two studies found to have analysed spatial contamination levels in a property. (Van Dyke et al., 2009) detected methamphetamine in areas away from where the simulated cooking was conducted, but there were very few samples taken. Conversely, Wright et al. (2019) conducted comprehensive sampling of a property including the wall layers, flooring, and possessions that had been introduced into the house by the new residents. Thus, highlighting the need for further research into the distribution of methamphetamine to minimise the impact of THEM.

5.5 Conclusion

The results from this study could have considerable ramifications for residential occupants' or owners' health and well being, and also have significant associated economic costs. It is clear that thirdhand exposure from previous methamphetamine contamination can cause significant health effects, and remediation is costly. However, with the implementation of standardised methods, accredited training, and a regulatory framework, would significantly reduce uncertainties for those that engage with these members. Consequently, future research should focus on best practice approaches to ensure detection and remediation are found and implemented.

6. METHAMPHETAMINE CONTAMINATION BASED ON THE EXPERIENCE OF ENVIRONMENTAL HEALTH OFFICERS

This chapter describes the experiences of Environmental Health Officers (EHOs) when handling clandestine laboratories and methamphetamine contamination related enquiries. There have been two manuscripts published during the course of the PhD.

The first manuscript analysed the challenges that EHOs faced during the COVID-19 pandemic and how they managed these issues to protect public health. This work also raised the concern that due to an increased workload, tasks that were time intensive, such as handling clandestine laboratories, could not be investigated in a timely manner.

The second manuscript assessed the experiences and concerns of EHOs when managing a clandestine laboratory or methamphetamine contamination enquiry from members of the public. Since the methamphetamine testing and decontamination industry is unregulated, it provides another layer of challenges when managing a property identified as a clandestine laboratory.

These manuscripts were both published during the course of the PhD.

Public health challenges facing environmental health officers during COVID-19: methamphetamine contamination of properties

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6.1 Introduction

The World Health Organization announced the COVID-19 global pandemic to be a Public Health Emergency of International Concern on 30 January 2020 (WHO, 2020). Many governments from around the world, including Australia, the US, China, and the UK, responded by implementing strict public health interventions. Globally, police, Army Reserves and other military services were used to enforce measures that included closing borders to overseas travellers, limiting group gatherings, and applying social distancing regulations (Leece, 2020). Despite adopting mitigation strategies, in some countries (e.g. China, Spain, Italy and Brazil), the spread of disease surpassed containment measures (Walensky & del Rio, 2020). Within countries, there have also been hotspots of infection, and even more stringent containment methods, such as lockdowns – which limited the movement of all residents – have been implemented in high-risk locations (Walensky & del Rio, 2020). Throughout 2020, social distancing regulations have changed the way people interact with each other and there has been a significant increase in public health messages for hand hygiene, sanitation and self-isolation (Garfin et al., 2020; Islam et al., 2020; Mheidly & Fares, 2020). Every country has faced increased and, in some cases, overwhelming demands on healthcare (Ferguson et al., 2020), increased unemployment (Mamun & Ullah, 2020; Morrow-Howell et al., 2020), and economic uncertainty (Coates et al., 2020; Dietrich et al., 2020).

6.2 Environmental health workforce

Environmental health officers (EHOs) are frontline educators and enforcers of the public health sector. They have the multifaceted task of ensuring public safety through infection control, water quality, food safety, waste management, chemical exposure and climate change. It has already been determined the environmental health role is overlooked in Australia, the US, UK and South Africa ("Environmental Health Workforce Act of 2019," 2019; Lowry, 1990; NEHA, 2020; Whiley et al., 2018), and that it is difficult to recruit and retain employees in this field (Bartosak, 2012). Tasks assigned to EHOs in response to the pandemic varied across countries. For example, a recent analysis of Australia, UK, US and Portugal EHOs showed that they were assigned with a range of COVID-19 tasks that varied between states and locations (Rodrigues et al., 2021). Responsibilities included, but were not limited to, isolation and quarantine compliance checks, new food safety inspections for takeaway options, and advising social distancing restrictions for public spaces (Rodrigues et al., 2021). As of December 2020, time delays in 'normal' activities are to be expected due to the increased workload, as EHOs are still assessing and investigating environmental health issues while working safely within current restrictions. As time and pressure mounts, we can expect the emergence of new environmental health challenges and exacerbation of existing challenges, such as food safety, healthy homes and climate change (Brooks et al., 2019; Shezi et al., 2019). It is critical that this workforce is adequately resourced to ensure public health regulation is enforced, and a risk-based approach is used to tackle these emerging issues (J. C. Smith et al., 2021). The response to

COVID-19 has resulted in a sudden and single-minded shift in priorities (Al-Khateeb, 2020; NEHA, 2020). When faced with so many immediate issues associated with the worldwide pandemic, it can be difficult to maintain existing public health activities. This paper will use methamphetamine contamination of properties as an example of an emerging environmental health issue that has been exacerbated due to COVID-19. This highlights the need for an increased labour force to ensure that this overlooked but critical public health workforce is supported to ensure public health protection now and into the future (Ryan et al., 2020; Whiley et al., 2018).

6.3 Arising public health issues due to COVID-19

As this pandemic continues to move across the globe, it is predicted there will also be a surge in mental health issues such as depression and anxiety (Pfefferbaum & North, 2020), and increased domestic violence (Mesa Vieira et al., 2020). There are also a significant number of environmental health issues that have arisen due to COVID-19 (Table 7) and the enforced restrictions, including home isolation. Methamphetamine contamination of properties is an issue examined below in detail through the lens of the COVID-19 pandemic and the 'new normal' world we live in. It is essential that public health workers do not overlook these non-COVID emerging issues of concern and quickly identify control strategies to minimise the potential for detrimental impact on public health during and beyond the COVID-19 pandemic.

Table 7. Environmental health issues of increased concern due to restrictions form the COVID-19 pandemic.

Environmental health issue	Normal process	Current concern	References
Take away food options	EHOs will come and assess the take-away food handling procedure	• Many businesses that never offered a take away option are now using it as a lifeline to save their businesses. • There are delays in assessing food premises due to the increased workload, so some businesses may be offering take-away prematurely.	(U.S. Food & Drug Administration, 2020; Yapp & Fairman, 2006)
Main Wastewater treatment	Only toilet paper should be flushed through wastewater	• Many people have resorted to using unflushable products due to the lack of access to toilet paper. • This means the sewer system is under pressure from blockages.	(Gosselin, 2020; Smart Water Magazine, 2020)
Onsite wastewater treatment	Limited amount of time spent at home and only toilet paper is flushed into the septic tank	• Residents are spending more time at home, therefore their septic tanks are being used more. • The system is having inadequate time to process and separate the particles that can cause overflow and blockages.	(Gosselin, 2020; O'Dowd, 2020)
Methamphetamine contamination in properties	Contamination testing would be conducted before contacting a remediation specialist to clean the property	• People are less likely to bring contractors into their home due to home isolation measures and uncertain employment • Residents are spending more time at home which increases exposure in a contaminated property	(Deziel et al., 2020; Wright et al., 2017)

Mould or dampness in properties	Depending on the severity of the situation, some can be treated by the resident otherwise, it will be a remediation specialist	• Due to the increased amount of time in the home, health effects of mould or dampness issues could also increase. • Depending on the location, the country could be in lockdown, and it may be difficult finding a remediation specialist.	(Davies et al., 2004; Hope & Simon, 2007)
Overcrowding or squalor	This would normally be investigated based on a complaint	• Based on the increased close contact with people in the same home, they are at a high risk of transmitting other infectious diseases.	(Favas, 2020)

6.4 Methamphetamine contamination of properties

Methamphetamine is a synthetic drug that is illegally used and manufactured all over the world. The 'ice-like' crystalline structure has become increasingly popular and is commonly injected or inhaled through smoking. The most common methods for manufacturing methamphetamine employ combinations of lithium from batteries, ammonia from household cleaner, phosphorus, iodine and acids, resulting in toxic by-products or volatile organic compound (VOC) contamination (Owens, 2017). This accounts for the harmful nature of the residues from the precursor chemicals and their by-products, as well as the drug itself.

It has been well established there are health hazards involved with entering clandestine laboratories, especially for first responders (Thrasher et al., 2009). If the illegal drug activity is not discovered by law enforcement, it is likely the property will not be adequately cleaned prior to new residents moving in, posing a potential public health risk. Contamination from personal users or clandestine laboratories can become absorbed by structural components within a property such as walls, ceilings, and flooring (Abdullah & Miskelly, 2010; Van Dyke et al., 2014). Smoke and VOCs can be deposited and re-released again when disturbed. A study of housing walls by Wright et al. (2019) found that methamphetamine had penetrated the outer paper, the inner gypsum wall and the inner paper layer In contact with the wooden structure. This dispersion could be attributed to vapour intrusion through the layers, or mobility via vapour movement or moisture in the roof space and down the cavity walls (Wright et al., 2019).

In a controlled methamphetamine cook performed by (Van Dyke et al., 2009) airborne emissions moved from the manufacturing location and spread throughout other rooms in the property. Martyny et al. (2008) studied simulated smoking and found that residues can also travel by surface contact and air movement through air conditioner vents or foot traffic. Homes with ducted air conditioning have piping that distributes air throughout the home; therefore, potentially circulating residual methamphetamine and chemical by-products (Wright et al., 2016a). These airborne emissions can be readily absorbed by porous items including toys, bedding and soft furnishings (Martyny et al., 2007; Morrison et al., 2015; Wright et al., 2019),which can be disturbed and redistributed. Wright et al. (2019) also demonstrated that residues persisted for at least five years after manufacturing had ceased, and new possessions introduced to the property became contaminated. Notably, this is an understudied area, and these estimates provide only a superficial assessment of the resilience of methamphetamine contamination.

6.5 Adverse health effects of methamphetamine-contaminated properties

Adverse health effects due to methamphetamine contamination can be experienced by anyone in contact with the residues (enHealth, 2017). However, the health problems are non-specific and can be attributed to a range of other causes before contamination of a property is considered and investigated. Children are

most at risk of increased exposure to methamphetamine and health impacts due to their body size, developmental stages, inhalation exposure and physical contact with surfaces (Messina et al., 2014; Wright, Kenneally, et al., 2020). In a recent case study of 63 individuals by Wright, Kenneally, et al. (2020) adults, adolescents and children experienced adverse health effects after being unknowingly exposed to methamphetamine through third-hand use and manufacture of the drug. The amount of time family members spent living at the contaminated property varied from several days to 10 years (Wright, Kenneally, et al., 2020). Common health issues experienced by children and adolescents included but were not limited to behavioural and cognitive effects (79%); sleeping issues (72%); respiratory effects (62%); and eye and skin irritation (55%) (Wright, Kenneally, et al., 2020). Brewer et al. (2016) also demonstrated that between 0.056 and 0.34 ng/mL methamphetamine was absorbed by three racehorses transported for six hours in a contaminated float. Therefore, higher quantities of methamphetamine could be expected to be absorbed with long-term exposure. During the COVID-19 global pandemic, there has been increased time spent in isolation. This means that people unknowingly living in methamphetamine-contaminated properties will have experienced significantly higher levels of exposure. The increased amount of time spent inside the home may increase the number or severity of health effects experienced. There are also people aware that their home is contaminated but who are unable to leave or remediate due to their financial situation. This is exacerbated as the capacity to investigate methamphetamine-contaminated houses has been impeded by social distancing measures (Ferguson et al., 2020), the imminent heath concern of SARS-CoV-2, and increased workload of EHOs (NEHA, 2020; Rodrigues et al., 2021). The ability for owners to undertake assessment and remediation has also been impacted by economic hardship (Coates et al., 2020).

The health issues detailed above highlight the importance of remediating methamphetamine contamination. Australia has the National Clandestine Drug Lab Remediation Guidelines (Australian Crime Commission, 2011), New Zealand has the standard (NZS 8510:2017) (Standards New Zealand, 2017), and the US has the Voluntary Guidelines for Methamphetamine Laboratory Cleanup (US EPA, 2013) available for guidance. However, to date, there is no legislation or regulatory organisation in these countries to ensure compliance (Kuhn et al., 2019). The Australian Voluntary Code of Practice for methamphetamine-contaminated properties released in November 2019 provided clarification and insight into the specific details recommended for remediation (Wright, 2019).

In Australia, when a suspected clandestine laboratory has been detected, police and forensic services investigate the property and then notify the local council. EHOs will contact the property owner and work with them to ensure they understand the ramifications of this investigation and risks to public health. EHOs enforce remediation under the relevant state or territory Public Health Act. EHOs are also able to use their powers as an authorised officer of their state or territory to issue a notice that prohibits entry onto the property until the site has been remediated and the success of the remediation validated (Australian Crime

Commission, 2011). To avoid bias towards businesses, most states and territories require property owners to independently seek a remediation company. However, the Western Australian Department of Health has a different approach and issues a list of approved forensic testing, cleaning companies and laboratories that EHOs can recommend to owners (Government of Western Australia, 2020). Engagement with property owners and validation experts is a time-intensive and challenging process, as financial and inadequate remediation problems often arise. It is recommended that EHOs are involved in the assessment, remediation process and validation to ensure appropriate measures are taken before notices are removed (Australian Crime Commission, 2011). This process is time-consuming and costly; as such, it is a significant burden and risk to public health, especially for those of a lower socioeconomic demographic.

6.6 Methamphetamine manufacturing, usage, and increased exposure during COVID-19

During 2020, drug shipments hidden and imported among legal products were restricted by the reduction in international air and sea cargo (Dietze & Peacock, 2020). Similarly, border closures restricted the movement of drugs and precursors. The closure of entertainment venues and restrictions on public gatherings will have reduced the usual supply routes. While it is difficult to predict, it is reasonable to presume other tactics may have been adopted to combat these accessibility issues (Giommoni, 2020). Anticipated changes include altered chemical composition of the drug (Hamilton & Stevens, 2020), increased street prices, increased local manufacture and inventive ways to smuggle drugs internationally, such as in hand sanitiser bottles (Australian Border Force, 2020).

6.7 Conclusion

EHOs continue to be overlooked and under-resourced despite the invaluable role they have played in response to COVID-19 (NEHA, 2020; Ryan et al., 2020). To expedite and support society’s recovery, it is essential that we minimise the burden of other controllable health risks; this includes the identification of emerging environmental health challenges. While EHOs have been prioritising the implementation, education and regulation of social distancing measures, it is essential that exacerbated and emerging threats such as methamphetamine contamination of properties are not overlooked. Sufficient resources, support and recognition of the EHO workforce will enable them to identify and mitigate risks early to minimise long-term public health consequences ("Environmental Health Workforce Act of 2019," 2019; Gerding et al., 2020; Heidari et al., 2019).

An investigation into the prevalence of methamphetamine related enquiries to local government Environmental Health Officers

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6.8 Abstract

Methamphetamine contamination of residential properties remains a serious public health concern for members of the public. External stakeholders including Environmental Health Officers (EHOs) and testing and remediation technicians are engaged on investigating whether contamination has occurred from manufacturing or smoking processes. More specifically, local council EHOs are responsible for managing clandestine drug laboratories when notified by police and also for responding to public enquiries. However, the full scope of these contaminated properties is not seen by any single stakeholder, making it very challenging to quantify these situations. To evaluate the prevalence of methamphetamine related enquiries from the general public to EHOs, this study surveyed and interviewed officers from around Australia. It was found that public enquiries were infrequent with only 6% of respondents having received enquiries in the last month, which indicates that people are seeking information from other sources. Interestingly, there were case study scenarios that also mentioned issues with awareness and the flow of information. Concerns regarding difficult cases, police notifications, and site visits were also highlighted. The results of this study provide a benchmark of how methamphetamine related cases are managed and highlight the need for trustworthy information that is available to EHOs, governments, industry members, and the public in a unified location.

6.9 Introduction

Illegal drug production is a significant issue worldwide (United Nations Office on Drugs and Crime, 2023a). In particular, it has been shown that the methamphetamine market is continuously increasing (United Nations Office on Drugs and Crime, 2023a). Concerningly, it is estimated that only 1 in 10 clandestine drug laboratories are discovered by law enforcement (Newell, 2008). Methamphetamine is an amphetamine-type stimulant that is found in several different forms: a waxy substance, a white powder, and a crystalline form (Chomchai & Chomchai, 2015; McKell et al., 2016). Of the extensive list of illicit drugs that can be manufactured, methamphetamine is of particular relevance to public health due to the potential long-term contamination arising through its manufacturing and smoking processes (Kuhn et al., 2023; United Nations Office on Drugs and Crime, 2023b). Methamphetamine contamination of residential properties can occur in cars, holiday homes, workplaces, and even public spaces (Diaz, 2023; Gilbreath, 2013; Vandeveld, 2004; Weisheit, 2008). Consistent exposure to methamphetamine can lead to Thirdhand Exposure to Methamphetamine (THEM) syndrome, which is a compilation of health effects including respiratory issues; itchy, watery eyes; skin irritation; and behavioural issues (Kuhn et al., 2023).

Environmental Health Officers/Practitioners (EHOs/EHPs, referred to as EHOs from here on) are the front-line educators and regulators of public health for local government (Whiley et al., 2018). They manage an array of issues in local government areas including food safety, immunisations, mosquito management,

septic tanks, swimming pools, and building contamination associated with clandestine drug labs (Heidari et al., 2019; Kuhn, Walker, Wright, et al., 2021). Health protection departments from around the world recognise the challenges associated with clandestine labs and methamphetamine contamination (Bardsley et al., 2018; Barn et al., 2012; Kuhn et al., 2019; Petruželka & Barták, 2020; Puljević et al., 2021; Scaturro, 2024; United States Environmental Protection Agency, 2021). While many of the recommendations are issued from individual states within nations, it can also be difficult to ascertain who accepts responsibility for cases involving methamphetamine contamination. Currently, in Australia, when a council is notified of a clandestine drug lab by police, an EHO will manage the potential health issues associated with property contamination by using regulatory tools such as Public Health Acts or Residential Tenancies Acts (Australian Crime Commission, 2011). However, if a resident suspects methamphetamine contamination in their home from a previous homeowner, tenant or visitor, this contamination is not captured under similar regulatory tools. Thus, the management of these cases can vary depending on the state, territory, and council location.

This study investigated EHO responses to methamphetamine contamination of homes and analysed some of the challenges that were raised by local government EHOs in Australia. This information will inform the development of future guidelines and professional practice in managing the increasing risk of THEM.

6.10 Materials and Methods

A mixed-method approach that followed an explanatory sequential design was used to collect information about current EHO professional practice related to methamphetamine contamination. This included an online survey with quantitative and qualitative questions, followed by phone interviews that were qualitative in nature. This study was approved by the Flinders University Human Research Ethics Committee (HREC) (Project number 5574).

6.10.1 Survey Participants

Two methods of participant recruitment were used for the survey. The first was to invite attendees of the Environmental Health Australia (EHA), the national Environmental Health professional body, at the national conference held in Tasmania in September 2022 to participate. To ensure that the survey was also available to those that had not attended the EHA conference, an email was sent out after the conference to all EHA members, inviting them to participate. The survey link remained open for 21 days to ensure that participants could complete the questions without time pressure.

6.10.2 Survey Questions

The survey was a short, targeted survey that consisted of nine questions in a combination of multiple choice, order of prevalence, and free-text opportunities for extended answers. Qualtrics® (Utah, United

States) is an online platform that was utilised to create and host the survey data. A Quick Response (QR) code was generated for participants to access the survey on their mobile devices. The questions are available in Appendix E.

6.10.3 Phone Interviews

Participants of the online survey were asked whether they were willing to participate in a follow-up phone interview to share additional information on their experiences with regulating methamphetamine contamination in properties. The follow-up phone interviews were approximately 30 min in duration and followed eight scripted questions (Appendix F). These interviews were initially transcribed by speech to text software Otter.ai®(version 3.46.1-7898), and then imported into NVivo 12®, which is a qualitative data analysis software.

6.11 Results

6.11.1. Survey Participants

A total of 79 EHOs participated in the online survey, with representation from every state and territory across Australia with the exception of the Northern Territory. The highest number of responses came from Queensland (27%), followed by Tasmania (21%), South Australia (18%), New South Wales (14%), Western Australia (9%), Victoria (9%), and the Australian Capital Territory (2%).

6.11.2 Phone Interviews

Of the 79 survey respondents, 20 people that agreed to a phone interview in the survey and were subsequently contacted via email, of which 18 participants shared their experiences. Western Australia (7) had the highest number of interviewees, then Queensland (4), then Victoria (2), South Australia (2), Tasmania (2), and New South Wales (1). The interviews were allocated 30 min; however, some respondents were happy to discuss their experiences for longer. The following results present a combination of the survey and interview responses.

6.11.3 Public Enquiries

Separate to police notifications, only 6% of respondents stated that they had received 1–5 public enquiries about methamphetamine contamination in a month, and the remainder said that they do not receive them on a regular basis. It is likely that concerned residents are seeking information and advice elsewhere. When members of the public do make enquires, the most prevalent methods are email, website submission, phone, and then in-person.

EHOs were asked whether enquiries had increased during the COVID-19 pandemic. Eighteen percent said yes, which could be attributed to residents becoming more aware of suspicious activities in their neighbourhood due to the increased time spent at home during lockdowns (Walby & Joshua, 2021; Wright, 2021). There were also factors such as cost and public stigma that disincentivise people from reporting

clandestine labs or suspected contamination. One EHO reported that due to the size of the council area, they had recruited a call centre that was given scripting to screen their phone calls.

"*They would more than likely be told (from the call centre staff) that unless they have an identified source, we would not take the complaint."* (Participant 1)

Another EHO stated

"*If we have a resident that is concerned that their neighbour is making meth or some weird odours, we get them to contact police first.*" (Participant 3)

Similarly, other EHOs reported that they have had interactions with building inspectors that have used presumptive testing kits while surveying the structural integrity of a property.

"*I've had those sort of reports sent to me where they're positive. And that is really tricky, because, you know, we know that this sort of limitations in terms of that sort of testing. And, you know, when it's just that sort of testing that is been provided, it's hard for us to do anything about that*." (Participant 2)

6.11.4 Council Notices

When a house has been reported as contaminated by police, EHOs should put a notice on the council's property file that states the property must be tested and remediated. This is to ensure that the council members are aware that the property must be decontaminated prior to being sold or rented. The results show that 22% of interview participants stated that they were monitoring a vacant property that required remediation within their council area.

EHOs can initiate another process that attaches a notification to the property title which informs future owners of the previous works. This will also advise them if there is any outstanding work that is required. During an interview, an EHO in New South Wales highlighted that there are two different ways to attach it to a property title. There is a compulsory title, and a voluntary title. It is dependent on the lawyer or conveyancer which property title search they request, or whether they complete both.

"*If they only get the 1492 which is the compulsory one, they can miss out on the 1495 notification of the clan lab.*" (Participant 5)

When a notation is added to a property file, it is not permanent. They can be removed from the file with no previous history. This issue was also raised by other EHOs in Victoria and Western Australia. If a record of these notices was kept, it could offer grounds for subsequent tenants to seek testing or remediation advice. Other EHOs mentioned property managers not checking the property file before having building contractors commence work, and potential buyers having to conduct multiple council searches to establish if their newly purchased property had been flagged as a clandestine lab.

6.11.5 Site Visits

There was also a divide between councils that chose to do site visits for clandestine labs and those that did not. Of the 10 councils answering this question, 80% said that they did not allow their officers to visit the property, while 20% said that they do go onsite. Councils that did go on site to clandestine labs would go to obtain photos of the drug paraphernalia as it was being removed by law enforcement, and to talk with the officers to gain any further information that could be used to support their public health notification on the property.

"*It really helps when you start getting all the reports coming from the consultants as well, it helps you be able to get your head around it and make sure that the clean-up and assessments have been done properly*." (Participant 5)

The main determining factor for attendance to onsite inspections was a concern for the officers' safety. Many officers were a part of small teams or even sole EHOs for regional councils, thus having a secondary officer present was unfeasible.

"*Our attitude here is that we do not do onsite visits for clan lab jobs. It's much safer that way*." (Participant 1)

6.11.6 Police Notifications

The survey results found that due to the inconsistent nature of clandestine lab notifications, some local council areas receive more than others. This results in a variation in clandestine lab case management experience. When EHOs were asked how many clandestine drug labs their council has handled in the last month, 14% selected 1–5, and 86% said that they do not receive them on a regular basis. These were total clandestine drug lab notifications from the police.

The different approaches to visiting the site or not were sometimes impacted by the lack of detail provided by law enforcement in their notifications. From the phone interviews, there was a divide between councils that maintained a good relationship with local law enforcement and those that did not. This was linked with receiving sufficient details in written clandestine laboratory notifications. Unfortunately for councils that do not have a connection with the local police officers, they are not permitted to call law enforcement for clarification if there are inadequate details in the notification.

"*My main issue is the fact that the notification process gives us so little information for myself and for any of my staff who are looking to attend (the site)*." (Participant 4)

6.11.7 Difficult Cases

Survey participants were asked if they had ever experienced a difficult case or one that could not be resolved. There were 58% that said yes, and 42% said no. Many of these cases involved the homeowner

facing criminal charges and being in jail. In this instance, it is difficult to obtain information on who will be managing the contaminated property.

"*The simplicity of having the ability to get in contact with that person or have a law enforcement member find out and get information of who is going to deal with it on the criminal's behalf*." (Participant 4)

Of the phone interviews, 27% said that they were monitoring vacant properties from cases that were not resolved. They would drive past and sometimes discuss the vacancy with the surrounding neighbours to ensure that no people moved in while the house was still contaminated.

"*One (clandestine lab) was in a caravan that was located inside a shed at the back of a residential property. So we touched base with the Department of Transport with our concerns. If they just drive away with this van, we'll never know where the van is ever again. So we called them. This was all complete news to them, they basically had no real responsible knowledge of what can or should happen*." (Participant 6)

This participant described a scenario involving a mobile clandestine lab resulting in a contaminated car. They reported that in this instance, the Department of Transport and the insurance company were both highly proactive and had the vehicle written off and destroyed. However, this scenario raised an emerging issue of contaminated cars and caravans, which are currently not captured under any of the currently guidelines of regulations.

6.12 Discussion

It has been established that EHOs are often under-recognised for the multifaceted work they perform to protect public health (Whiley et al., 2018). This could be contributing to the lack of awareness from the general public on who they should contact if they suspect methamphetamine contamination of their property, whether it be from a clandestine lab or due to smoking. The results of this study suggest that members of the general public are not fully aware of the role of local government EHOs in this space. This is a concerning issue that needs to be addressed as it may be further exacerbating the problem of under reporting. This would result in many cases not being investigated and, therefore, not appearing in data or statistics. It would be highly beneficial to have a national or state campaign to raise awareness in communities on the role of EHOs, especially with respect to methamphetamine contamination.

6.12.1 Issues with Consistency

The main finding of this study was that there is little consistency in the management of clandestine labs and methamphetamine contamination cases, both within and between states and territories. This issue can be partially attributed to the bimodal distribution of council experience related to methamphetamine contamination of properties, meaning that they were either highly experienced or had very little to no experience. This poses a challenge for the profession and local governments, as it can be difficult to

maintain the knowledge skill set if it is not consistently utilised, or if the experienced or knowledgeable EHOs leave the organisation.

The absence of clear and detailed directives is another contributing factor. Currently in Australia, there are the National Clandestine Drug Lab Remediation guidelines and the Voluntary Code of Practice for the assessment, remediation, and validation of former clandestine drug laboratories and other methamphetamine contaminated properties (Australian Crime Commission, 2011; Wright, 2019). The national guideline provides foundational information that is applied Australia-wide; however, it is focused on labs detected by law enforcement and has broad recommendations that can be open to interpretation. The voluntary code of practice provides guidelines on the finer details involved in assessment and remediation for members of the testing and remediation industry. Enquiries about methamphetamine contamination, however, require a slightly different scope which has not been captured or focused on in the same way.

6.12.2 Governmental Responsibilities

enHealth are the national body that develops guidance for Australian health protection departments related to environmental risk factors that impact human health. Health protection departments are within the state government network and maintain strong connections with local government. The main responsibility for local government is to decide how to regulate according to what is suitable for their community and council members (Dollery et al., 2006; Mees et al., 2019). How they choose to engage with their constituents and how they manage any enquiries varies with each local government. This is leading to inconsistencies in the profession, with many potential financial and public health consequences. As such, there is a need to generate a standard approach that encompasses all aspects of methamphetamine contamination to ensure consistent messaging is given to all regulations, industry members as well as the general public, and other external stakeholders.

The enHealth guidelines for *Legionella* control provide a good example of how a national approach has been established and used in conjunction with state and territory based guidelines (enHealth, 2015). For example, South Australia have the Guidelines for the Control of *Legionella*, which are focused on the installation, maintenance, testing, decontamination, and inspection of manufactured water systems (Health Protection Programs, 2013b). Western Australia has taken the approach of developing the Prevention and control of Legionnaires' disease Code of Practice. This document covers the same key sections as the South Australian guidelines, but also includes potting mix and soils, and occupational safety and health regulations (Commission for Occupational Safety and Health, 2010). Thus, each state and territory have their own regulations and legislation to support their EHOs to manage this environmental health risk, but they are based on a nationally consistent enHealth framework.

The process and management of a clandestine lab or contaminated property has a similar structure, with the national framework and then guidelines coming from the states and territories. The Australian Clandestine Drug Laboratory Remediation Guidelines provide some guidance, and the enHealth document considers the public health perspective. Yet, this study shows that there needs to be improvement in the level of detail that is comprehensible to members of the public that are concerned not just about clandestine labs but also about contamination from smoking (Australian Crime Commission, 2011; enHealth, 2017). The main issue is that these guidelines are broad in nature and too generalised to be utilised. More specific information and guidance is required to ensure that they are beneficial and translatable to those that seek to use it.

6.12.3 Collaboration

Open communication between councils and law enforcement is essential for a good working relationship. Kacperska and Łukasiewicz (2020) have described knowledge sharing between individuals as being integral for any organisation, and as being invariably linked with trust and efficiency. Similar to hoarding and squalor cases, which are also managed by local government EHOs, clandestine labs are multifaceted situations which often include financial problems, child and/or animal neglect, and public health safety concerns (Messina et al., 2014; Norman et al., 2021; Watanabe-Galloway et al., 2009). For hoarding and squalor cases, many of these problems arise from a combination of physical impairment and mental health issues (Gleason et al., 2021). Contact with these services is initiated by EHOs; however, many stakeholders are required to be involved to resolve a hoarding and squalor case; these include (but are not limited to) rubbish removal contractors, law enforcement, and community health services (Staley, 2005; Vandeveld, 2004). As with hoarding and squalor cases, when dealing with methamphetamine contamination, there needs to be a more consistent approach. This should be applied to the information that is provided by police, to engagement with other services, and also to ensuring that these services understand the role that EHOs have.

6.13 Conclusions

The purpose of this study was to understand the prevalence at which members of the public contacted the EHO at their local council. The results indicate that the general public are seeking their information from sources other than local government, and they also highlight the variability in case management. It can be concluded that while some good processes are in place, a more streamlined approach is ideal for EHOs, members of the public, and those in the decontamination industry.

6.14 Recommendations

This study highlights that a national framework for EHOs and heath protection departments would assist in streamlining the management of methamphetamine contaminated properties. This would need to be all encompassing and should include contamination arising through smoking, previous contamination of

unknown origin identified by the general public, and contamination of mobile assets such as vehicles and caravans.

In particular, the participants of this study stated that it would be highly beneficial to have an approved list of testers, remediators, and occupational hygienists. Currently, Western Australia is the only state that provides a publicly available list of approved contractors for methamphetamine decontamination. This is an interesting approach given that there is no regulation or accreditation for this industry. Some states have legislation that prevents them from recommending companies for any services, which ensures that there is no bias or conflicts of interest. A regulatory body, adequate training, and an accreditation process are necessary to act as a benchmark for those working within industry. This will ensure a fair course of action is taken to help support members of the public and others seeking an experienced and qualified professional. Consistent information and transparency will build trust for the remediation industry members, within in the profession, and in the community.

To address some of these concerns, there is a need for a toolkit that can be used by EHOs, law enforcement, and the general public to provide consistent information and a clear process to follow. It is evident that some members of the public are unsure of who to contact; therefore, website information that outlines the differences between clandestine labs and smoking can assist those in need. Ideally, an accessible platform should be populated with helpful information and maintained to ensure that the content is readily available and remains current. This proposal could begin with a single state and then expand to both align the current practices and also meet the needs of other states and territories to ensure consistency.

6.15 Limitations

This study provides insight into local government EHO interactions with members of the public about methamphetamine contamination, but it does not represent all council areas. In conjunction, the number of responses varied between states, thus further research in this area should be conducted to provide a more robust and unified answer to some of these questions.

6.16 Supplementary Materials

The following supporting information can be found in Appendix E for the Survey questions and Appendix F for the Interview questions.

6.17 Author Contributions

Conceptualization, E.J.K., K.E.R., and H.W.; methodology, E.J.K., K.E.R., and H.W.; investigation, E.J.K.; writing—original draft preparation, E.J.K., G.S.W., H.W., J.W., and K.E.R.; writing—review and editing, E.J.K., G.S.W., H.W., J.W., and K.E.R.; supervision, K.E.R., H.W., G.S.W., and J.W. All authors have read and agreed to the published version of the manuscript.

6.18 Funding

There was no external funding for this research.

6.19 Institutional Review Board Statement

This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Flinders University Social and Behavioural Research Ethics Committee (SBREC) in South Australia (Project number 5574).

6.20 Informed Consent Statement

The authors thank the participants of this study for their time and

contribution. Informed consent was obtained from all subjects involved in the study.

6.21 Data Availability Statement

Data is not publicly available, however it can be provided by contacting the corresponding author.

6.22 Acknowledgments

The authors thank the participants of this study for their time and contribution.

6.23 Conflicts of Interest

The authors declare no conflicts of interest.

7. DISCUSSION AND CONCLUSION

The research presented in this thesis investigated health effects associated with thirdhand exposure to methamphetamine contamination. This was undertaken guided by these five objectives:

- The current literature was reviewed to identify the health effects and symptoms that are associated with exposure to methamphetamine contaminated environments. Thirdhand Exposure to Methamphetamine (THEM) syndrome was proposed as a collective term for these non-specific symptoms and health impacts.

- Currently, in Australia the industry responsible for the assessment and decontamination of methamphetamine contaminated environments has no regulation or accreditation. Industry members were surveyed and interviewed to gain insight into what methods, chemicals and equipment are being used. The study found that most businesses had a conflict of interest in that they were offering both testing and remediation services to clients. However, many business owners were advocating for regulation of the industry through standardised approaches. This would reduce unethical practices and increase transparency and trust from members of the public.

- One of the findings from the industry survey was that 17% of businesses were using presumptive methamphetamine test kits exclusively to detect contamination. Considering these findings, the next research objective was to assess the accuracy and efficacy of these immunoassay-type tests being used. This study found that these presumptive tests are more sensitive than their advertised detection limit of 0.5 µg methamphetamine. Presumptive tests therefore provide a reliable preliminary screening assessment for contamination. However, this can have serious financial implications for a positive result if the testing company uses these without verification from laboratory testing. Furthermore, there are health implications for the resident. The uncertainty of the situation could cause unnecessary stress and anxiety when perhaps the lab test result is below the recommended limit.

- The survey of industry businesses also highlighted that there was significant variation in the location that samples were taken within a potentially contaminated house. Therefore, a study was undertaken to ascertain distribution patterns of methamphetamine present in a contaminated property. The results showed that contamination levels vary between locations just a few centimetres away from

each other which can have significant ramifications for a resident or tenant living within the property. It is difficult to determine if a house has been adequately decontaminated by taking the minimum five samples as recommended by the Clandestine Drug Laboratory Remediation guidelines. This research emphasises the need for multiple samples to be taken to fully assess the level of contamination present.

- The Environmental Health profession (Environmental Health Officers [EHOs]) are responsible for the regulation of public health risks such as methamphetamine contamination of properties. During the COVID-19 pandemic EHOs' workload drastically increased. A review was conducted to explore the implications that this increase in workload had on EHOs' capacity and role associated with methamphetamine contamination related enquires. This snapshot was written during that pandemic, and it was predicted that EHOs had to take on extra tasks, and it was unknown what repercussions isolation and lockdowns would have with regards to methamphetamine contaminated properties.

- Post-lockdowns, a survey was conducted to further investigate the current practices of EHOs in response to public concerns and complaints and to establish whether community members were contacting EHOs with methamphetamine contamination related enquiries. This study found only 6% of participants were contacted from concerned residents, which suggests that people are acquiring their information from other sources that may not necessarily be reputable. The development of a website with the available evidence-based research is recommended to ensure people have access to valid information when making an informed decision.

7.1 The public health response to methamphetamine contamination of properties

Throughout this thesis there were three issues that consistently underpinned other factors that arose. These issues were: 1. adverse health effects; 2. the need for industry regulation, and 3. The need for a consistent approach to remediation. These three are invariably interconnected (Figure 16). Without the improvement of industry practices, the risk to public health through thirdhand exposure to methamphetamine will be exacerbated by ineffective decontamination.

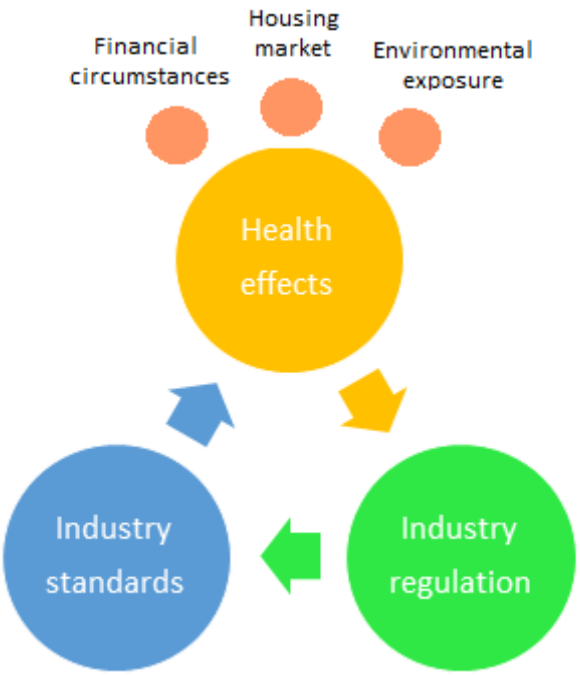

Figure 16: The underlying factors of methamphetamine decontamination in properties

7.1.1 Health effects

This section is focused on identifying factors that can impact the methamphetamine decontamination process and invariably influence health impacts.

7.1.1.1 Environmental exposure

The time taken to determine whether a premises is contaminated with methamphetamine can be significant. As described in Chapter 1, the health effects associated with THEM are non-specific and can potentially be attributed to other illnesses. People live busy lives that have daily activities in multiple locations, such as work, school, sports, shopping, and faith-based organisations. This was a challenge observed by contact tracers during the Covid-19 pandemic (Almagor & Picascia, 2020). It also illustrates how difficult it can be to determine the source of an illness.

Additionally, THEM health impacts can manifest in a number of ways depending on the individual and their co-morbidities, lifestyle, diet, employment, and their environmental conditions (Bodai et al., 2018). This demonstrates that even recognising that there is a THEM problem can take months, or even years, prolonging initiation of testing and remediation.

It is likely that the extra amount of time that people spent in their houses during the peak of the pandemic meant greater exposure without the normal work, school or extra curricular daily activities (Alfano & Ercolano, 2020). This would be especially true for those countries and states that imposed strict lockdowns for prolonged periods. The importance of indoor air quality was highlighted as people began to focus on the spread of disease and the role the interior of their homes plays (Elsaid & Ahmed, 2021). Even without the pandemic, it is estimated that most people spend approximately 90% of their time indoors (Cincinelli & Martellini, 2017), with 75% of that inside their home (Goldstein et al., 2021).

7.1.1.2 Financial circumstances

The financial impact resulting from methamphetamine contamination can vary greatly. Since testing for methamphetamine is not mandatory, people may purchase a house where contamination is not known or disclosed. This results in the new owners having to cover all of the testing, remediation and validation costs themselves. All the while, they could potentially have nowhere to live, and no way of knowing how long this decontamination process could take.

As for landlords, some insurance companies that offer cover for those impacted by clandestine drug lab activity or contamination in their investment property (Wright, 2019). The tenants have presumably been removed due to the Police raid and subsequently issued an eviction notice. This is not an easy process to follow, and owners can be offered an inadequate amount that does not cover the entire remediation costs. While this is not a fair outcome, there are also owners that are not covered by their insurance and must pay all of the remediation costs out of pocket. Sometimes owners are unable to afford these upfront costs which means the investment property must remain vacant with the council notice. Local council EHOs will randomly check on properties with outstanding notices to ensure they are not tenanted. However, this scenario is particularly focused on Police detection of a clandestine drug lab.

7.1.1.3 Housing market

Australia's housing market is currently undergoing a housing crisis. Since the beginning of this research in 2020, Australian property prices saw an annual increase to 23.7% in December 2021 (Australian Bureau of Statistics, 2022), and currently Perth is experiencing the highest year on year increase for 2024, at 18.6% (CoreLogic, 2024). At the time of writing in 2024, the national housing listings has increased by 2.6%, and a 14% decrease for the number of foreclosed houses listed, when compared to 2023 (Shagina, 2024). However, the total number of rental vacancies for February 2024 has continued to decrease as it sits at 1.0%, which is a 0.1% reduction from January 2024 (Christopher, 2024). Also in Australia, as rental vacancy

numbers declined, rent bidding was common but has since been prohibited by five of the eight states and territories (Consumer Affairs Victoria, 2023; Consumer Building and Occupational Services, 2023; Department of Energy, 2023; Fair Trading, 2023; Justice and Community Safety Directorate, 2023; Northern Territory Government, 2024; Residential Tenancies Authority, 2024).

When there is suspected methamphetamine contamination by a tenant, this often does not bode well for the tenant, who can be seen as a 'problem' tenant. Unless this property is tested and the results are freely provided to local council, there is no mandatory remediation step required. Instead, it could be considered more cost effective to end the lease of the 'problem' tenant and engage a new tenant without concerns of methamphetamine contamination. This is a concerning loophole that could be potentially impacting any 'whistleblower' tenants concerned about their health. With these factors in mind, tenants do not want to raise any issues if they are in a stable tenancy (Power & Gillon, 2022). Mould, general maintenance, plumbing, electrical issues, and suspected methamphetamine contamination are all issues that would be tolerated to ensure ongoing tenancy (Chisholm et al., 2020; Riggs et al., 2021). Compounding the issue, inflation has led to an increase in the cost of living by 17% over the past two years and have health implications of their own (Black et al., 2024).

7.1.2 Industry regulation

During the course of this work, it was revealed that the methamphetamine decontamination industry is not isolated in campaigning for overall regulation. Remediation and restoration technicians involved with emergency events such as flooding, fires, and mould also face similar challenges (Bourova et al., 2022). This problem arises particularly when a catastrophic weather event has occurred and there is a high demand for industry experts to restore homes.

According to the National Clandestine Drug Laboratory Remediation Guidelines in Australia, a technician with experience and suitable qualifications should be conducting site assessment and validation (Australian Crime Commission, 2011). While environmental health, engineering, science and occupational hygiene are all offered as tertiary qualifications, there are also a number of courses offered by educational providers that grant the term 'occupational hygienist' (Australian Institute of Occupational Hygienists, 2022). It is possible that these qualifications are inadequate for appropriate risk assessment and management of contaminated properties. Thus overall, introducing regulation for methamphetamine testing and remediation would require assessment and integration of all stakeholders that are engaged with this industry.

7.1.3 Industry standards

There is currently a standard being developed through the Institute of Inspection Cleaning and Restoration Certification (IICRC) in conjunction with a committee of industry collaborators, the IICRC S900 Standard for Professional Remediation of Precursors, Drug Residues, and Associated Chemical Waste (Institute of Inspection Cleaning and Restoration Certification, 2024). Securing a standard that will become the foundation for methamphetamine decontamination is a step in the right direction, however changes to industry practices take significant time to implement. During this time, it is important that those engaging with industry members have access to correct information. It appears that managing a contaminated property is challenging for those not knowledgeable in this industry.

From the outset, it appears that there is an existing framework to use, and by following the prescribed steps results in a clean house. While the Clandestine Drug Laboratory Remediation Guidelines offer some guidance, it is very broad in nature (Australian Crime Commission, 2011). There are a range of nuances associated with methamphetamine contamination, and once the issue begins diverging from the framework path, complexities not covered by the guidelines arise. For example, the smoking of methamphetamine is not considered, therefore there are no recommendations for this route of contamination and exposure. The presence of methamphetamine should be considered as a risk to human health, regardless of how the contamination occurred. Complexities of methamphetamine contamination, how it occurs, identification, and testing and decontamination; combine to create difficulties associated with risk assessment. The development and implementation of regulations and standards will provide a more consistent and robust decontamination approach.

7.2 Limitations

The findings of this research should be examined in conjunction with the study limitations outlined below.

The available literature for methamphetamine contamination comes from two main perspectives, clandestine drug labs and the repercussions for those who use methamphetamine. There is a significant body of research for both areas, however, thirdhand exposure is more aligned with the middle ground between the two. Thus, there is a small body of research in comparison with the other perspectives, but this with the proposition of THEM aims assist in making new research easier to find.

The industry members that participated in either the survey and/or the interview were a self-selected sample. The answers were from industry members that agreed to participate, and it could be presumed that they were conducting themselves in a professional manner. Thus, it could be said that the responses had a bias toward members that were working ethically and advocating for regulation in the industry.

The house samples that were taken before and after remediation were representative replicates. Since the purpose of samples after remediation were to determine whether the decontamination was successful, true replicate locations could not be sampled. Nevertheless, the position and height of the representative replicates was kept as consistent as possible.

7.3 Future research

The findings from the research presented in this thesis identified some key gaps in knowledge and areas for future research.

- There is more sampling that could be conducted to better understand the spatial distribution of methamphetamine that occurs through smoking. This could also be conducted with the use of Computational Fluid Dynamics (CFD) to model the vapour dispersion.

- The health effects of long-term, chronic exposure to methamphetamine contamination should be explored. There is limited information currently available for both the assessment and the health effects.

- The relationship between methamphetamine and electrical appliances should be investigated.

- Determining what flooring types can be effectively remediated could reduce the financial burden for home owners needing to decontaminate their house.

- Assessing the level of remediation that is achievable with various chemicals and approaches would be valuable. This is particularly difficult as some are patented or licenced products that are recommended for use.

- Investigating other contaminated spaces including, cars, and caravans where cooking or smoking methamphetamine is likely to have taken place. Assessing the contamination, fabrics, exposure levels would be present within a vehicle.

- Research that documents the progress of methamphetamine contamination (similar to that of the asbestos history) could inform practice.

7.4 Recommendations for regulation and practice

There have also been several areas highlighted during the course of this work that warrant recommendations for the testing and decontamination industry:

- The introduction of an open and accessible website that contains current and available information with regards to methamphetamine contamination. This would ensure that people no matter their location or affiliations could access evidence based information and make informed decisions.
- To understand and support EHOs with the current information to aid them in protecting public health.
- The development of accredited training for the industry. Things to consider include the length of time for accreditation and refresher courses.
- A regulatory framework that becomes the foundation for the decontamination industry that will provide a formal register for members of the public to engage with a qualified and experienced technician. This would also facilitate concerns and complaints.
- To establish a method for declaring conflicts of interest to maintain transparency for those engaging with industry members.
- The successful implementation of standard methods, equipment and chemicals, in conjunction with regulation of the industry.

7.5 Conclusion

Methamphetamine contamination in residential properties is a significant public health concern. The overall aim of this research was to explore the assessment and remediation of Australian properties contaminated with methamphetamine. Valuable insight was gained into the unregulated methamphetamine testing and decontamination industry which established that there were conflicts of interest but also advocation for regulation of the industry. This prompted the analysis and efficacy of presumptive tests that were found to be highly sensitive and detected methamphetamine below the recommended limit of 0.5 µg per 100 cm^2. The spatial distribution pre and post remediation was investigated and determined that a single sample is not a suitable indicator of contamination within a room.

While these aspects are industry specific, the public health perspectives from EHOs were also examined. During the Covid-19 pandemic, the increased workload of EHOs was explored as a concern for time-consuming cases such as clandestine drug labs. Post-pandemic, EHOs were surveyed and interviewed to establish the occurrence of public enquiries about methamphetamine contamination. The findings of this study suggested that members of the public were not contacting EHOs about their concerns and therefore may be seeking information elsewhere.

As mentioned in the discussion, the three components that consistently appeared from this research were health effects, industry regulation and standardisation. If only one of these is addressed, then the public health issue will continue. Furthermore, it is important to note that the unregulated practices, the conflicts of interest, and the impacts on unwitting residents are continuing to occur at the present time. Thus, having a searchable term THEM will enable researchers, clinicians and EHOs to identify some of the symptoms by bringing together diverse reports and data that will raise awareness.

APPENDIX A. INDUSTRY SURVEY - FLINDERS UNIVERSITY SOCIAL AND BEHAVIOURAL RESEARCH ETHICS COMMITTEE APPROVAL (PROJECT NUMBER 8634)

Dear Emma,

Your conditional approval response for project 8634 was reviewed by the Deputy Chair of the Social and Behavioural Research Ethics Committee (SBREC) and was **approved.** The ethics approval notice can be found below. Please also note the important information regarding COVID-19 Virus below.

HREC TRANSFER PROJECT FORM

ResearchNow Ethics & Biosafety is the new online platform for human research ethics at Flinders University. It can be accessed via Okta (add the "ResearchNow Ethics & Biosafety" chicklet to your dashboard) and allows researchers to apply for human research ethics approval, including modifications, online.

We note that your current project will expire after 31 December 2020. As you may be aware, all current projects approved under the old system that do not expire on/or before 31 December 2020 will need to be transferred into the new online system. Therefore, we would like to request that you complete the short HREC Transfer Project Form. To transfer your project, please:

- login to ResearchNow Ethics & Biosafety through your Okta dashboard. ResearchNow Ethics & Biosafety will need to be added to your Okta dashboard via the "+ Add Apps" green button (top right) in the first instance.
- Ensure you are on the "Home page", you will see "Work Area" at the top of this page.
- Select the "Create Project" tile from the left hand "Actions" menu.
- A pop-up appears. Type in the "Project Title" and in the "Main Form" drop-down select "HREC Transfer Project Form".
- Click "Create" and save your project application form.
- Select "Project Information" under "Questions", complete the form and submit it.

During the transfer, you can also modify your existing project.

APPROVAL NOTICE

Project No.:	**8634**
Project Title:	Determining the methods used by commercial cleaners to decontaminate homes that have been contaminated with methamphetamine
Principal Researcher:	Ms Emma Kuhn
Email:	emma.kuhn@flinders.edu.au
Approval Date:	15 May 2020
Ethics Approval Expiry Date:	**23 January 2024**

The above proposed project has been **approved** on the basis of the information contained in the application, its attachments and the information subsequently provided.

APPENDIX B. INDUSTRY SURVEY QUESTIONS

Methamphetamine Remediation Survey

This research project has been approved by the Flinders University Human Research Ethics Committee in South Australia (Project 8634). For queries regarding the ethics approval of this project please contact the Executive Officer of the Committee via telephone on +61 8 8201 3116 or email human.researchethics@flinders.edu.au

Participation for this survey is voluntary. You may choose not to answer any questions and are free to withdraw at any time.

Please read this Letter of Introduction for this research

Please read this Information Sheet for further details about this online survey

Your company Postcode _____

Do you offer a methamphetamine remediation service to the public?

- ○ Yes
- ○ No

Have you been contracted to clean a methamphetamine contaminated property?

- ○ Yes
- ○ No

How many queries for the methamphetamine remediation service do you receive per month?

- ○ I do not receive them on a regular basis
- ○ Less than 10
- ○ 10-20
- ○ 20-30
- ○ 30+

How many properties would your company clean in a month?

- ○ I do not clean them on a regular basis
- ○ Less than 10
- ○ 10-20
- ○ 20-30
- ○ 30+

How many contaminated properties have been cleaned by your company?

- ○ Less than 10
- ○ 10-50
- ○ 50-100
- ○ 100-150
- ○ 150-200
- ○ 200+
- ○ Not applicable

How many former clandestine laboratories (seized by police) has your company remediated in the last 10 years?

- ○ Less than 10
- ○ 10-50
- ○ 50-100
- ○ 100-150
- ○ 150-200
- ○ 200+
- ○ Not applicable

What areas does your company service?

- ○ Central city suburbs
- ○ Northern suburbs
- ○ Eastern suburbs
- ○ Southern suburbs
- ○ Western suburbs

Are you apart of a franchise?

- ○ Yes
- ○ No

How many services does your company offer? (this is the only compulsory question)

Select all that apply

- [ ] Methamphetamine testing
- [ ] Pre-cleaning inspections and testing
- [ ] Post-cleaning inspections and testing
- [ ] Clandestine laboratory remediation
- [ ] Personal use remediation
- [ ] Not applicable

For your testing service, what kind of sampling methods are used?

- [ ] Do It Yourself (DIY) presumptive screening tests
- [ ] Wipe samples (that are analysed in a laboratory)
- [ ] Not applicable

What is the brand/s of the screening tests used?

_____

_____

Have you independently validated this brand of presumptive test through a NATA accredited laboratory prior to use?

- ○ Yes
- ○ No

What kind of analysis is performed on the wipe samples taken?
Select all the apply

- ☐ Discrete (individual) samples
- ☐ Laboratory composite samples
- ☐ Field composite samples

What is the name the laboratory the wipe samples are sent to?_____

What guidance do you use for your sampling methods?

_____

_____

If there was suspected contamination in a bedroom, where would you sample from?

_____

_____

Do you provide photos to your clients?

- ○ Yes - how many? _____
- ○ No

What techniques are used to reduce the risk of cross contamination of sampling?

_____

_____

Do you prepare the remediation action plan?

- ○ Yes
- ○ No - who does? _____

Are there external factors that influence the materials and surfaces that you remediate in properties?

Select all that apply

- [ ] Cost limitations from client
- [ ] Instructions from insurance companies
- [ ] Instructions from property managers/owners
- [ ] Guidelines or reports - please specify _____
- [ ] Other_____
- [ ] Not applicable

What methods are used by your company to remove methamphetamine contamination?

Select all the apply

- [ ] Triple wash
- [ ] Alkaline wash
- [ ] Foam fog
- [ ] Ozone fog
- [ ] Encapsulation
- [ ] Other_____

What time frame do these methods require for airing/drying?

- ○ 1-6 hours
- ○ 6-24 hours
- ○ 24-48 hours
- ○ 48-72 hours
- ○ 72 hours
- ○ Not applicable

Are multiple treatments used together?

- ○ Yes - which ones? _____
- ○ No

How long is the resident required to be away from the property?

- ○ 1-6 hours
- ○ 6-24 hours
- ○ 24-48 hours
- ○ 48-72 hours
- ○ 72 hours +
- ○ Not applicable

Do you have a Safety Data Sheet for the chemicals used for remediation?

- ○ Yes
- ○ No

Could you provide the Safety Data Sheet numbers?

_____

Are these chemicals produced in Australia?

- ○ Yes
- ○ No (if not Australia, what country?) _____

Are multiple treatments used together?

- ○ Yes - which ones? _____
- ○ No

What techniques are used to reduce the risk of cross contamination?

_____

_____

Have you found problems with using any of these chemicals?

- ○ Yes - please specify) _____
- ○ No

Do you use any specialised equipment?

- ○ Yes
- ○ No

Please list equipment used:

_____

How frequently do you clean this equipment?

- ○ After finishing a job
- ○ Several times a day
- ○ Daily
- ○ Weekly
- ○ Other _____

Have you found problems with using any equipment?

- ○ Yes - please specify _____
- ○ No

What is the most common approach to the remediation of electrical items?

- ○ Remove and replace all
- ○ Remove and replace some
- ○ Clean all items

If some items are removed and replaced, please specify which ones.

_____

_____

If all items are cleaned, please specify what method is used.

_____

_____

Have you ever had to return to a property that you had cleaned?

- ○ Yes
- ○ No

Please describe the reason and the outcome

_____

_____

Have you been required to remediate a property that was insufficiently cleaned by another company?

- ○ Yes
- ○ No

How many occasions has this occurred?

- ○ 1-5
- ○ 5-10
- ○ 10-15
- ○ 15-20
- ○ 20+

Have you ever consulted any of these experts regarding the extent of contamination in a property?

- [ ] Another remediation company
- [ ] Occupational hygienist
- [ ] Building inspector
- [ ] Other _____
- [ ] Not applicable

How many occasions has this occurred?

- ○ 1-5
- ○ 5-10
- ○ 10-15
- ○ 15-20
- ○ 20+

What remediation and/or testing qualifications do you currently hold?

_____

_____

Would you like to participate in a phone interview to provide more depth to your answers?

- ○ Yes
- ○ No

For more details about the interview, please read this Information sheet

---

If you selected Yes for a phone interview, could you please provide some contact details and we will be in touch shortly.

- ☐ Phone number _____
- ☐ Preferred time to contact (e.g. Mondays after 1pm) _____

Would you like to be sent a copy of the publication or thesis chapter that contains these survey results?

- ○ No
- ○ Yes (please provide email address) _____

APPENDIX C. EHO SURVEY - FLINDERS UNIVERSITY SOCIAL AND BEHAVIOURAL RESEARCH ETHICS COMMITTEE APPROVAL (PROJECT NUMBER 5574)

Flinders UNIVERSITY

HREC Application Form

Understanding the prevalence of methamphetamine contamination in residential properties as experienced by Environmental Health Officers

ID:5574 Year:2022 Version:2

Project Details

Project Information

All research conducted by, and/or with, SA Health (including Southern Adelaide Local Health Network - SALHN) staff, patients, visitors, premises or data sets needs to be approved by an SA Health Human Research Ethics Committee. Once Ethics approval has been obtained from an SA Health Ethics Committee, please notify us by completing the "Cross-Institutional Approval Form" in the online system.

Teaching & Learning applications can only be submitted for the evaluation of teaching projects for research purposes.

Coursework applications can only cover student projects that are considered low risk and where research results will be disseminated beyond the University and interested parties. This **does not** cover above low risk, Honours, Masters by Research, or PhD student projects.

The definition for a clinical trial can be found here.

A1. Project Title

Understanding the prevalence of methamphetamine contamination in residential properties as experienced by Environmental Health Officers

A2. Type of Project

- (•) Research involving human participants
- ( ) Clinical trial involving human participants
- ( ) Teaching & Learning Program evaluation involving human participants
- ( ) Coursework application (Masters by Coursework student projects only)
- ( ) Research only involving existing and de-identified data sets

A3. Anticipated Start Date

The Committee cannot grant retrospective approval so data collection cannot commence until Ethics approval has been granted. Please note that the start date refers to the commencement of the data collection period. This is not linked to your PhD candidature, length of your funding agreement etc. as Ethics approval is only required for the duration of recruitment and data collection.

Please note: The start date cannot be changed after the commencement of the data collection.

24/09/2022

APPENDIX D. HOUSE CONTAMINATION

1 Method development

This chapter section describes the approach taken to develop the method that forms the basis of the research that is presented in the previous section (5.0-5.5).

1.1 Methamphetamine extraction – first experiment

Methamphetamine hydrochloride (Cayman Chemical) was prepared in known concentrations of 0.05, 0.2, 0.4, 0.6, and 0.8 µg per mL in methanol. One mL was added to a wipe that had been dampened with 3 mL methanol and placed in a 50 mL tube. These wipes were used in a number of methods (described below) to determine the most effective desorption and analytical approach.

To remove the methamphetamine from the wipe sample, 10 mL methanol was added to the 50 mL tube and put on a rotary mixer (Ratek, model R5M6) at 60 rpm for 10 min. Using a plastic syringe, 1 mL of the sample was filtered through a 0.22 µm nylon filter (Membrane Solutions®) into a 2 mL glass autosampler vial. This was repeated for all concentrations in triplicate with a 1 µL sample injection.

Mobile phase A was High Performance Liquid Chromatography (HPLC) grade methanol (Scharlab), mobile phase B was deionised water (Milli-Q®) with 0.1% formic acid (Sigma Aldrich). The column temperature was held at 40 °C, the collision-induced dissociation was at 30 V, and the overall run time was 15 min. The gradient started with 90% of mobile phase B at a flow rate of 0.2 mL/min and was held for 2 min. Mobile phase B then decreased within 7 min to 10% at the same flow rate, which was kept for 2 min. The 90% mobile phase B gradient was restored within 2.5 min and retained for 1.5 min. The Collison-Induced Dissociation (CID) was set at 30 for the mass spectrometer. An extracted ion chromatogram was generated for ions 91, 119, and 150 m/z which enabled both consistency and verification for methamphetamine.

1.2 Methamphetamine extraction – second experiment

Since the methamphetamine could not be detected in the samples in the experiment described above, the extraction method was repeated, with the volume of methanol increased from 10 mL to 20 mL. This was to ensure that the wipe was adequately submerged for migration of methamphetamine into the liquid phase. Twenty mL methanol was added to the 50 mL tube and put on a rotary mixer for 10 min. Using a plastic syringe, 1 mL of the sample was filtered through a 0.22 µm nylon filter into a 2 mL glass autosampler vial. This was repeated for all concentrations in triplicate. The gradient method from 5.4.1 was followed with a 1 µL sample injection.

1.3 Methamphetamine extraction – third experiment

Since the methamphetamine could not be detected in the samples in the experiment described above, the same wipes were used, but the sample injection volume was increased. This was to ensure that the volume injected into the LCMS was adequate for the methamphetamine to be detected.

Thus, using the known concentrations, 20 mL of methanol was added to a 50 mL tube and put on a rotary mixer for 10 min. Using a plastic syringe, 1 mL of the sample was filtered through a 0.22 µm nylon filter into a 2 mL glass autosampler vial. This was repeated for all concentrations in triplicate. The gradient method from 5.4.1 was followed with a 5 µL sample injection.

1.4 Methamphetamine extraction – fourth experiment

To increase the peak height of methamphetamine detected in the samples, the extraction process was altered to include sonication, evaporation and resuspension, and the injection volume increased. This was to determine whether the lack of detection was due to the concentration of the sample being near the lower limits of detection.

Thus, using the known concentrations described above, 20 mL of methanol was added to a 50 mL tube and put on a rotary mixer for 10 min, and then placed in an ultrasonic cleaner (CooperVision, model 895) for 10 min. Excess methanol was squeezed from the wipe, and the wipe was placed into a new, clean 50 mL tube. The 50 mL tube with the methanol was placed inside a Smoothflow TOUCH™ fumehood (Lab Systems Group) and left open for the methanol to evaporate. This process took three days. Once all the methanol had evaporated, 2 mL of fresh methanol was added and the residue was resuspended. The tube was put on the rotary mixer for 10 minutes, and the sonicator for 10 minutes. Using a plastic syringe, 1 mL of the sample was filtered through a 0.22 µm nylon filter into a 2 mL glass autosampler vial. This was repeated for all concentrations in triplicate. The gradient method from 5.4.1 was followed with a 5 µL sample injection.

1.5 Methamphetamine extraction – fifth experiment

To generate a calibration curve, external and internal standards were prepared and added as extra samples to the LCMS run. This was to verify the concentration of methamphetamine on the wipe samples and determine whether there was a difference in the extraction or detection of the wipe samples.

Using the known concentrations of methamphetamine described above, a 10 µg methamphetamine per mL concentration was also prepared in 20 mL of methanol and put in a 50 mL tube. The external standards of methamphetamine were prepared at concentrations of 10, 1, 0.1, 0.01, and 0.5 µg per mL in methanol. One mL was filtered through a 0.22 µm nylon filter into a 2 mL glass autosampler vial. The internal standard prepared was methamphetamine-D_9 (Cayman Chemical) at a 100 µg/mL concentration, and each sample was spiked with 50 µL.

For each of the known concentrations and the external standards, 20 mL of methanol added to a 50 mL tube and put on a rotary mixer for 10 min, and then sonicated for 10 min. Excess methanol was squeezed

from the wipe, and the wipe was placed into a new, clean 50 mL tube. The 50 mL tube with the methanol was placed inside a fumehood and left open for the methanol to evaporate. This took three days. Once all the methanol had evaporated, 2 mL of fresh methanol was added and the residue was resuspended. The tube was put on the rotary mixer for 10 minutes, and the sonicator for 10 min. Using a plastic syringe, 1 mL of the sample was filtered through a 0.22 µm nylon filter into a 2 mL glass autosampler vial. This was repeated for all concentrations in triplicate. The gradient method from 5.4.1 was followed with a 5 µL sample injection. The LCMS run was prepared as follows, the system and matrix blank samples, the prepared external standards, and then the known concentration wipe samples.

1.6 Methamphetamine extraction – sixth experiment

As the method described in 5.4.1 was not successful, despite extensive trouble shooting, it was decided that the National Institute for Occupational Safety & Health (NIOSH) 9111 method for Methamphetamine on Wipes by Liquid Chromatography-Mass Spectrometry be explored. The method and LCMS parameters outlined in 5.1.7 were followed, with the initial run only having known concentrations and the standard spiked solutions.

Methamphetamine hydrochloride (Cayman Chemical) was prepared in known concentrations of 0.05, 0.2, 0.4, 0.6, and 0.8 µg per mL in methanol. One mL of each concentration was added to a wipe that had been dampened with 3 mL methanol and placed in a 50 mL tube. One mL was filtered through a 0.22 µm nylon filter into a 2 mL glass autosampler vial.

2 Results

2.1 Methamphetamine extraction – first experiment

The first experiment was to determine if methamphetamine would be extracted from the wipe and detected on the LCMS. The methamphetamine could not be detected in the samples, but it was unclear what aspect was failing. Investigation into the extraction process was the second step.

2.2 Methamphetamine extraction – second experiment

This was to determine if the increased methanol volume would lead to the extraction and detection of methamphetamine. The methamphetamine could not be detected in the samples. Investigation into the detection process was the third step.

2.3 Methamphetamine extraction – third experiment

This was to determine if the increased sample injection volume would lead to the detection of methamphetamine. The small peaks that could be seen on the LCMS chromatogram were not discernible from other noise on the chromatogram, so it could not be confidently quantified (Figure 17). Investigation into concentrating the sample was the fourth step.

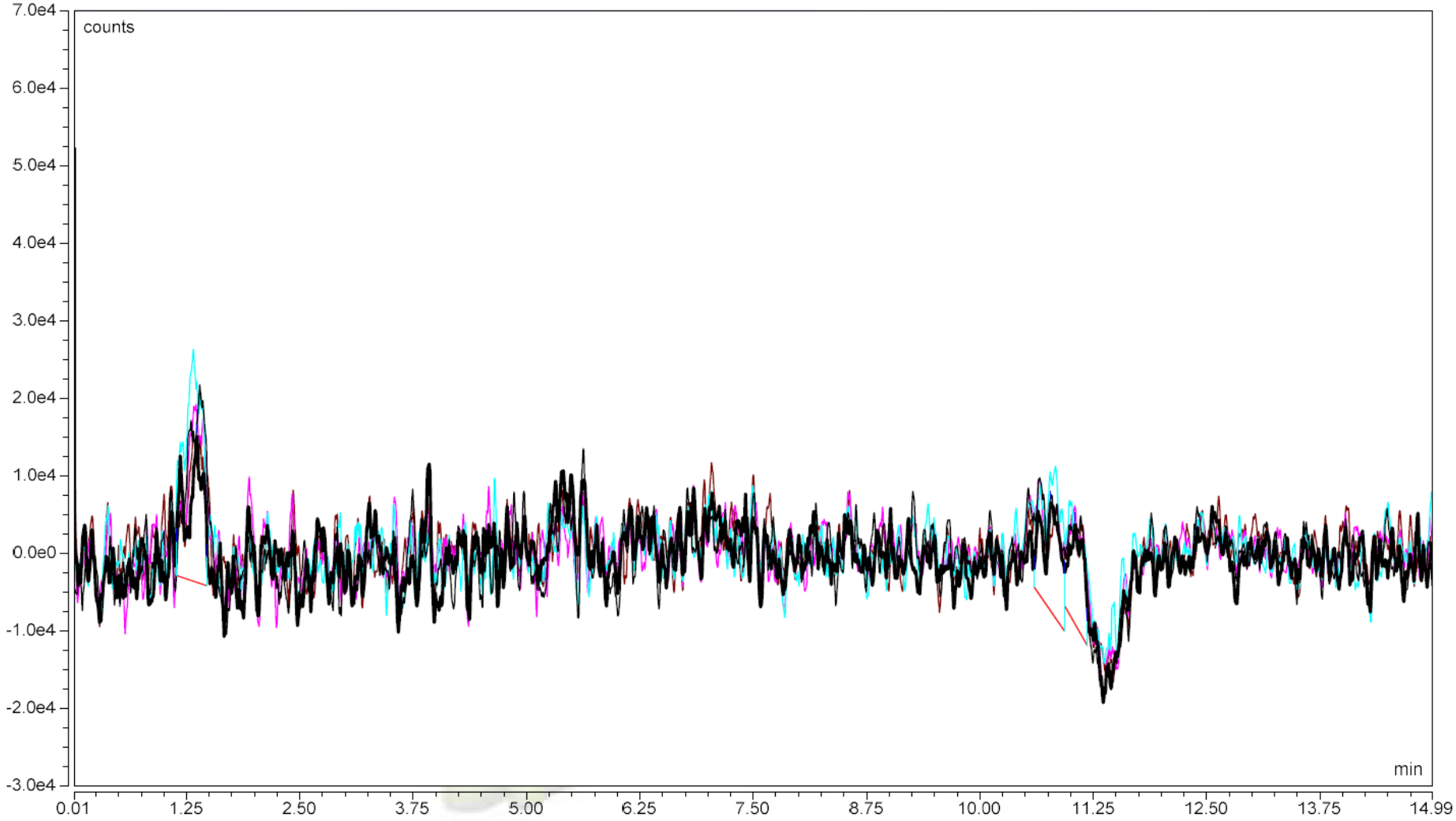

Figure 17: Small peaks could not be accurately defined or quantified

2.4 Methamphetamine extraction – fourth experiment

This was to determine if the issues with the detection of methamphetamine was due to the sample concentration sitting too close to the limit of detection. The methamphetamine peaks displayed on the LCMS chromatogram were larger and some were defined peaks (Figure 18). However, it was determined that external and internal standards were required to quantify the known concentration samples.

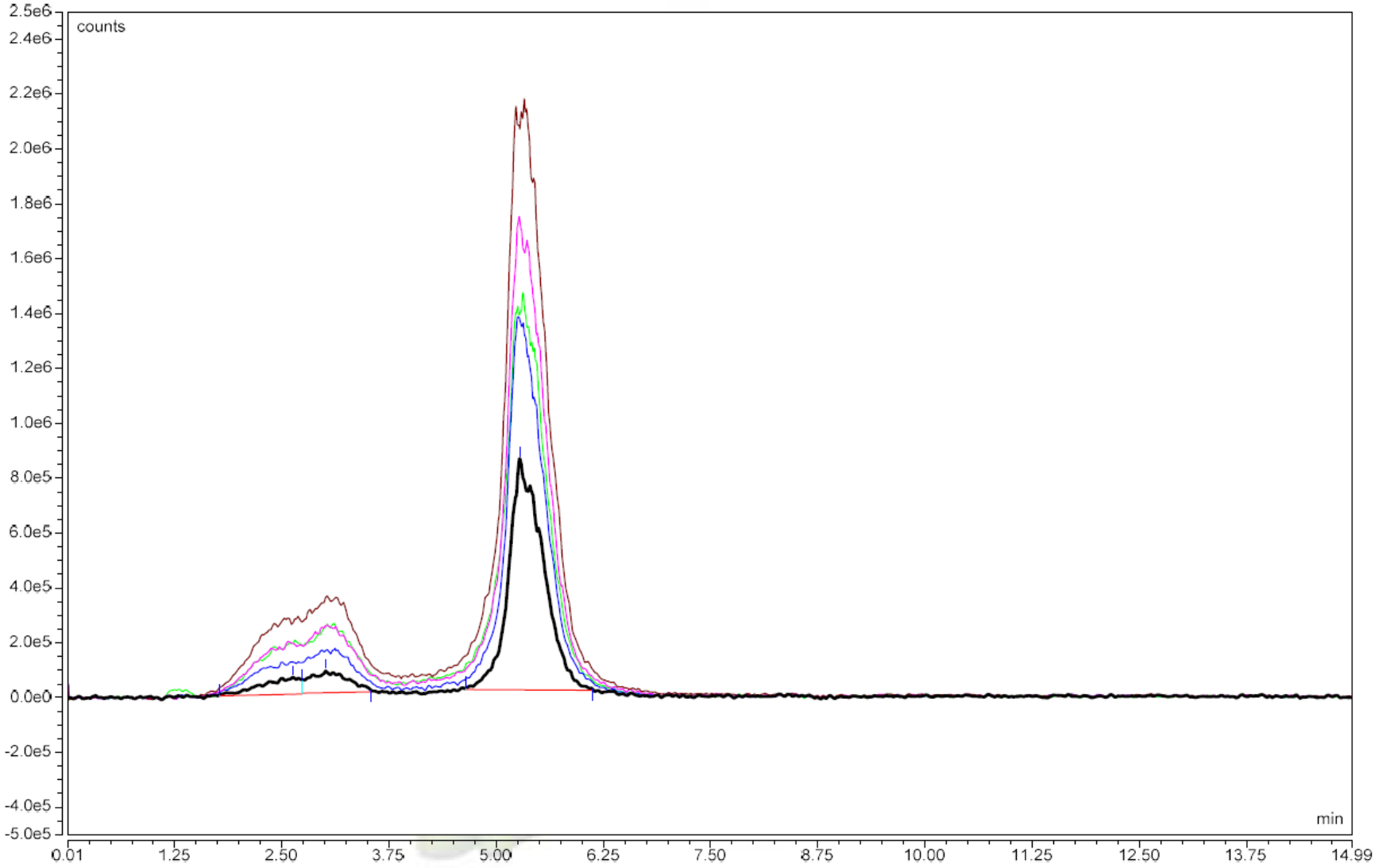

Figure 18: The injection volume of the LCMS sample was increased so the peaks were visible and defined

2.5 Methamphetamine extraction – fifth experiment

This was to evaluate whether the inclusion of external standards would be sufficient for a calibration curve to be created and determine whether methamphetamine was being adequately extracted from the wipe samples (Figure 19). A calibration curve could not be created with addition of external and internal standards, thus, determining differences between liquid and wipe samples was not possible. Investigation into following a standardised method to detect and quantify the methamphetamine present was the next step.

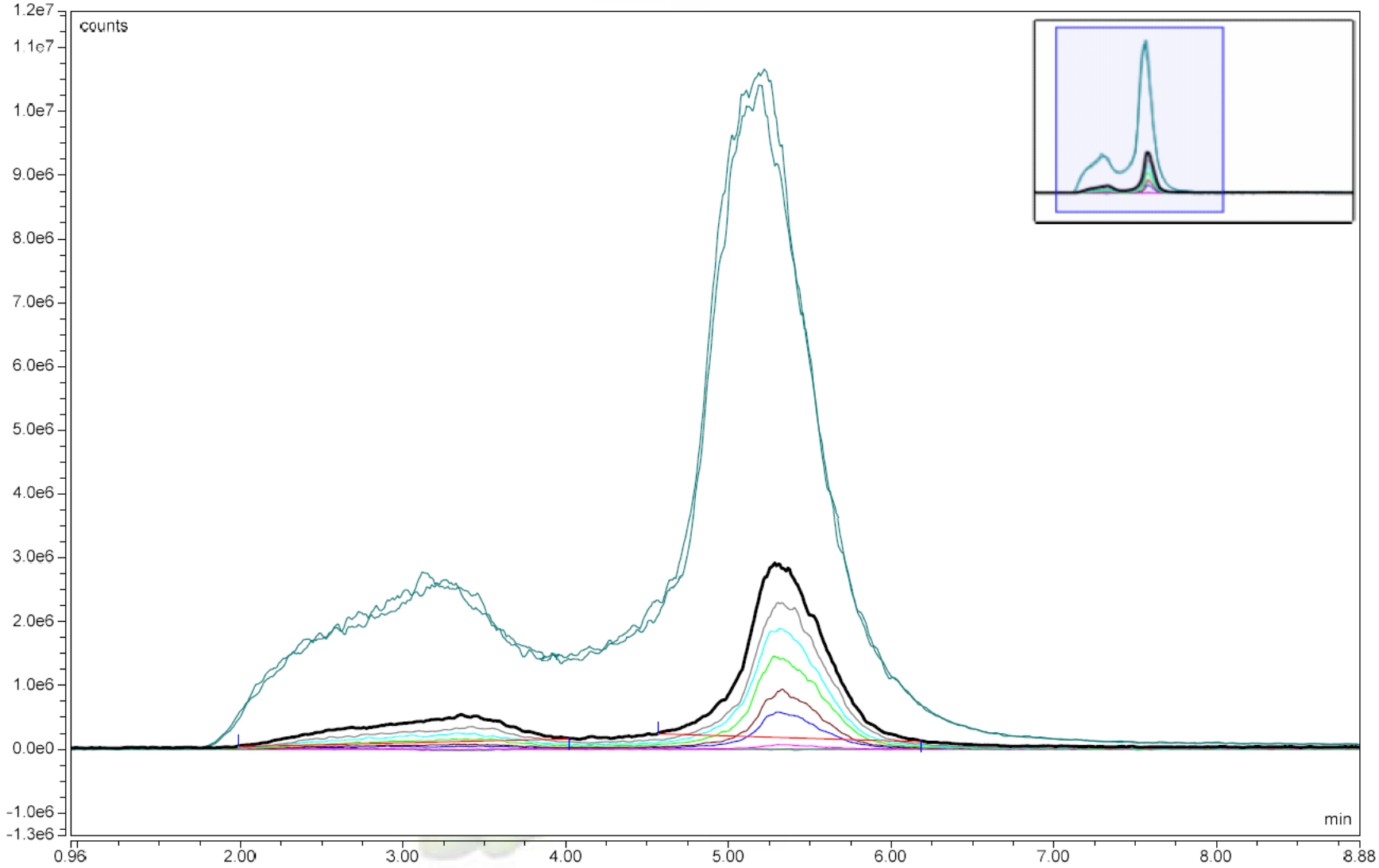

Figure 19: The ion peaks for the external methamphetamine standards 10, 1, 0.1, 0.01 and 0.5 µg per mL, and the known methamphetamine standards 0.2, 0.4, 0.6, 0.8, and 10 µg per mL

2.6 Methamphetamine extraction – sixth experiment

After following the NIOSH 9111 method, the calibration standards, the internal standards, and the known concentrations were successfully detected and calculated (Figure 20). This indicated that the method was optimised and could be used to analyse the house samples.

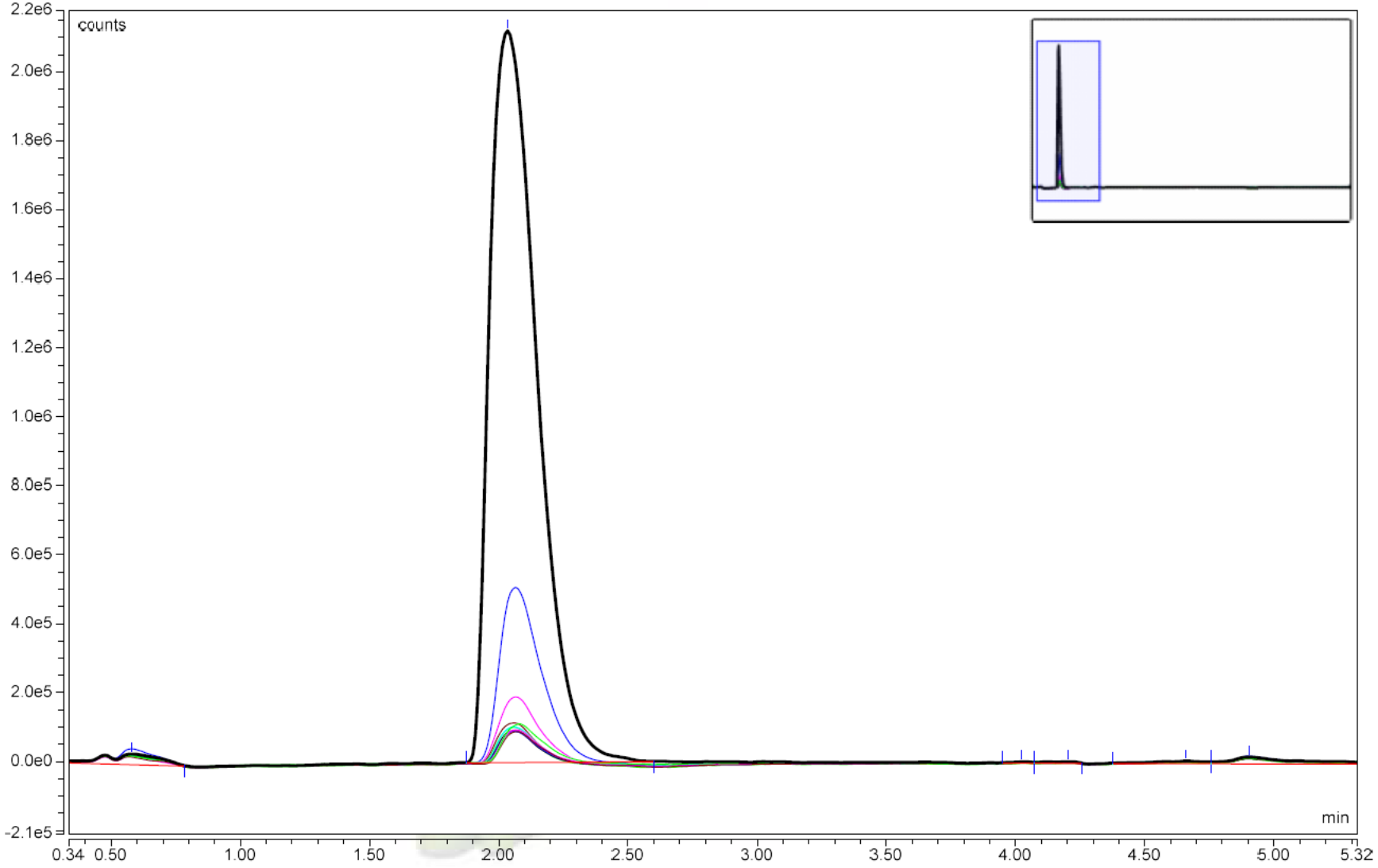

Figure 20: The first run using the NIOSH 9111 method with calibration and known concentrations with internal standards

APPENDIX E. EHO SURVEY – SURVEY QUESTIONS

EHO Survey

This research project has been approved by the Flinders University Human Research Ethics Committee (Project 5574). For queries regarding the ethics approval of this project, please contact the Executive Officer of the Committee via telephone on +61 8 8201 2543 or email human.researchethics@flinders.edu.au

Participation for this survey is voluntary. You may choose not to answer any questions and are free to withdraw at any time.

Please read Letter of Introduction for this research

Please read this Information Sheet for further details about this online survey.

This survey is based on your current council area.

Your state

- ○ Western Australia
- ○ Northern Territory
- ○ South Australia
- ○ Queensland
- ○ New South Wales
- ○ Australian Capital Territory
- ○ Victoria
- ○ Tasmania

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2. How many queries about methamphetamine contamination do you receive per month?

- ○ I do not receive them on a regular basis
- ○ 1-5
- ○ 5-10
- ○ 10-20
- ○ 20+

---

3. How have you received these enquiries? Select in order of prevalence (1-5)

_____ Email

_____ Website submission

_____ Phone

_____ In person

_____ Other

Have you had cases that are difficult or cannot be resolved? If so, please describe.

_____

_____

---

5. Do you think that Covid-19 has increased the frequency of methamphetamine contamination enquiries?

○ No

○ Yes - reason for your answer _____

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6. How many former clandestine laboratories (seized by police) has this council handled in the last month?

○ I do not receive them on a regular basis

○ 1-5

○ 5-10

○ 10-20

○ 20+

---

7. Would you like to participate in a phone interview to provide more depth to your answers?

- ○ No
- ○ Yes

---

8. If you selected yes for a phone interview, could you please provide contact details and I will be in contact shortly.

- ○ First name _____
- ○ Phone number _____
- ○ Email _____
- ○ Preferred days and time to be contacted

_____

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9. Would you like to be informed of the outcome of these survey results? If yes, please state if you would prefer a short summary and/or a copy of the publication.

- ○ No
- ○ Yes _____

APPENDIX F. EHO SURVEY – INTERVIEW QUESTIONS

Methamphetamine contamination EHO Interview

This interview is based on your current council area.

1. Do enquiries usually disclose why they believe there is methamphetamine contamination?
Yes
Sometimes
No

2. When speaking to public, what are most common questions about?
Clandestine labs (manufacture)
Personal use (smoking)
Businesses that provide testing services
Businesses that provide remediation services
Other

3. Does your council recommend any businesses to the public that offer testing or remediation services?
Yes
No

4. Have you handled a complaint or had negative experiences with businesses that provide testing and/or remediation services?
Yes
No

5. How often has this occurred?
I do not receive them on a regular basis
1-5
5-10
10-20
20+

6. Do you have a particular case that you found challenging that you would like to share with me? Please describe.

7. Do you feel like you have the tools to assist members of the public with methamphetamine contamination related enquiries?
Yes
No – please explain

8. Do you have any suggested improvements or comments about how methamphetamine contamination is handled on a council level?
No
Yes – please explain

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