OFFICE OF THE PRIME MINISTER'S CHIEF SCIENCE ADVISOR

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Methamphetamine contamination in residential properties: Exposures, risk levels, and interpretation of standards

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List of abbreviations

ADHD	attention deficit hyperactivity disorder
ATSDR	Agency for Toxic Substances and Disease Registry
BMDL	benchmark dose level
CDC	US Centers for Disease Control and Prevention
CDPHE	Colorado Department of Public Health and Environment
ESR	Institute for Environmental Science and Research
RfD	reference dose
LIM	Land Information Memorandum
NIOSH	National Institute for Occupational Safety and Health
OEHHA	Office of Environmental Health Hazard Assessment (California, USA)

1 Executive Summary

Background – the methamphetamine situation in New Zealand

- Methamphetamine is a powerful, highly addictive stimulant used illicitly in New Zealand and around the world. It is obtained either through smuggling into the country, or by being manufactured locally in clandestine laboratories (meth labs). These meth labs may be found in residential dwellings, commercial accommodation, and even vehicles.
- A dwelling can become contaminated with methamphetamine residues if the drug is manufactured or smoked within it. Smoking usually results in much lower residue levels compared with manufacture. The question that forms the basis of this report is whether, and at what level of detection, methamphetamine residue on household surfaces poses a risk to human health.

Detecting methamphetamine as a contaminant in dwellings

- International guidelines have been developed specifically for cleaning of contaminated premises after a meth lab has been discovered. These guidelines use the detection of methamphetamine below a specified low level after remediation as evidence that other hazardous chemicals and solvents associated with traditional methamphetamine manufacturing methods have been sufficiently cleaned away.
- In New Zealand, manufacturing methods have changed and now mostly eliminate the risks posed by other hazardous chemicals. Methamphetamine is therefore the primary contaminant arising from both manufacture and smoking. However, overseas guidelines developed for cleaning after manufacture have increasingly been used in New Zealand to suggest a need for methamphetamine testing more generally, regardless of whether or not manufacturing activity is suspected.
- In the absence of clear scientific and health information, there has been an assumption among the general public that the presence of even trace levels of methamphetamine residue poses a health risk. An industry of methamphetamine testing and remediation companies has emerged alongside these concerns. As a result, remediation of properties considered at risk has been undertaken – sometimes at great cost.
- This situation is largely unique to New Zealand – in other countries methamphetamine investigations focus mainly on identifying meth labs (or former labs), and remediating them when found. Non-meth lab contamination generally does not lead to any particular consideration or action. The question thus emerges, is the New Zealand approach over-precautionary or appropriate?

Methamphetamine exposure and health

- Passive, third-hand exposure to methamphetamine can arise through residing in a dwelling previously used as a clandestine meth lab, or where a significant amount of methamphetamine has been smoked. Former meth labs generally have relatively high levels of methamphetamine residue on sampled surfaces (levels greater than 30 µg of methamphetamine per 100 cm^2 surface area are thought to be indicative of manufacturing activity). There is some evidence for adverse physiological and behavioural symptoms associated with third-hand exposure to former meth labs that used solvent-based production methods, but these symptoms mostly relate to the other toxic chemicals in the environment released during the manufacturing process, rather than to methamphetamine itself.

- However, there are no published (or robust, unpublished) data relating to health risks of residing in a dwelling formerly used *only for smoking* methamphetamine. Yet, given the relatively low number of confirmed meth labs found, and the very low average levels of methamphetamine found in most houses that test positive for the drug, most New Zealanders will only ever encounter very low levels of residue that are the result of methamphetamine use.

Establishing health-based standards for methamphetamine exposure

- In New Zealand, from August 2010 until June 2017, the only available guidance for cleaning of contaminated dwellings was a Ministry of Health guideline intended to be applicable to former meth labs. This indicated an acceptable level (after cleaning) of 0.5 µg of methamphetamine per 100 cm^2 surface area, which was derived directly from an Australian risk assessment report that likewise focused on former meth labs.

- A 2016 risk-based review of these guidelines by the Institute for Environmental Science and Research (ESR) concluded that 2 µg/100 cm^2 is an appropriate precautionary clean-up guideline for methamphetamine-contaminated houses *not known to be former meth labs*. In June 2017 a new standard of 1.5 µg/100 cm^2 was selected as the clean-up level in the New Zealand Standard on the testing and decontamination of methamphetamine-contaminated properties (NZS 8510:2017), taking the ESR review into consideration. This threshold was chosen for reasons of practicality and did not distinguish between former labs and premises where methamphetamine was used.

Towards an evidential and health risk-based approach for managing potential exposure and contamination

- ESR analysis suggests that most houses in New Zealand in which methamphetamine can be detected have only low levels that are not widespread throughout the house. This situation is likely to be caused by methamphetamine use rather than manufacture. Less than 1% of the samples in the ESR dataset tested above 30 µg/100 cm^2, a level that is taken to indicate a property was likely used for manufacture. Even in situations of suspected manufacture, toxic compounds such as lead and mercury that are used in some methamphetamine production methods have not been found in New Zealand.

- It is important that guidelines for mitigation measures are proportionate to the risk posed, and that remediation strategies should be informed by a risk-based approach.

Implications for methamphetamine screening and remediation

- Given the low probability of encountering excessive levels of methamphetamine in properties where meth lab activity is not suspected, and also considering the very conservative nature of the standards with respect to the risks of adverse effects from third-hand exposure to methamphetamine, it is suggested that the guideline of 1.5 μg/100 cm^2 should not be universally applied.

- Testing is only recommended where meth lab activity is suspected or where very heavy use is suspected.

- For initial screening of properties, combining multiple samples taken throughout a dwelling into a single composite sample, as permitted in NZS 8510:2017, has limited value in accurately reflecting levels of risk, and depending on how the data are integrated can lead to quite misleading interpretation and false impressions of high exposure, triggering another round of expensive testing.

- There is merit in using tests that rapidly provide a simple positive or negative result in multiple locations for detection of higher levels (for example >15 μg/100 cm^2) on site, followed by sensitive testing targeted to areas that produce a positive signal to inform a decision to decontaminate. In most cases, if methamphetamine is not detected at this level anywhere within a property, there is little cause for concern unless there are other reasons to suspect methamphetamine manufacturing activity.

- Remediation is certainly warranted if methamphetamine levels signify that manufacture is likely to have taken place. Remediation includes removal of all potentially contaminated porous materials or items (furnishings, carpets) and cleaning of the contaminated surfaces, using the NZS 8510:2017 standard as a guide.

- Where lower levels are detected, remediation is often not justified. However, as low levels cannot definitively rule out manufacture, remediation involving cleaning down to the 1.5 μg/100 cm^2 standard may be prudent if there is also *reason to suspect previous meth lab activities*. This would be as a precautionary measure to remove other toxicants that may be present but not measured.

Conclusions

- There is currently no evidence that methamphetamine levels typically resulting from third-hand exposure to smoking residues on household surfaces can elicit an adverse health effect.

- Toxicity assessments and exposure dose models have deliberately adopted very conservative assumptions, with large safety margins built in.

- Taken together, these factors indicate that methamphetamine levels that exceed the NZS 8510:2017 clean-up standard of 1.5 µg/100 cm^2 should not be regarded as signalling a health risk. Indeed, exposure to methamphetamine levels below 15 µg/100 cm^2 would be highly unlikely to give rise to any adverse effects.

- This means that, because the risk of encountering methamphetamine on residential surfaces at levels that might cause harm is extremely low, testing is not warranted in most cases. Remediation according to the NZS 8510:2017 standard is appropriate only for identified former meth labs and properties where excessive methamphetamine use, as indicated by high levels of methamphetamine contamination, has been determined.

2 Background

2.1 Methamphetamine: therapeutic use to drug of abuse

Methamphetamine belongs to a class of drugs called stimulants. It is a legally prescribed medication in the United States for the treatment of attention deficit hyperactivity disorder (ADHD), obesity, and narcolepsy. The drug affects the brain and central nervous system by increasing the release of neurotransmitters including dopamine (a chemical associated with pleasure and reward), noradrenaline, and serotonin in the brain.

Because of its stimulant and euphoria-inducing properties, methamphetamine is commonly used as a recreational drug. It is usually smoked from a glass pipe, but it also can be injected, snorted or swallowed. In the short-term, users experience symptoms such as increased heart rate, attention, wakefulness, agitation, and decreased appetite. Longer-term use results in a constellation of side effects involving physical (weight loss, cardiovascular and organ damage), mental (anxiety and confusion, psychosis), and behavioural (a tendency towards recklessness and violence) aspects [1].

Methamphetamine is highly addictive at doses used recreationally, so this type of use often leads to continual drug-seeking behaviour and drug abuse. With repeated use over time, tolerance to the effects of the drug develops, and users require repeated and ever-increasing doses to achieve a 'high'. They may turn to crime to support their habit, or become involved with manufacturing and/or selling the drug. These factors further perpetuate the problem in the community.

2.2 The methamphetamine problem in New Zealand

Methamphetamine is not used therapeutically in New Zealand; it is classified as a Class A controlled drug under the Misuse of Drugs Act 1975. Due to the severity of the potential health risks posed by its abuse, and the substantial social costs and downstream burden on wider society, particularly the health and law enforcement systems, it carries severe penalties for possession, supply, and manufacture.

In New Zealand methamphetamine is commonly known as 'P', 'meth', and 'ice'. It is obtained either through smuggling into the country, or by being manufactured locally in clandestine laboratories (so-called 'clan labs' or meth labs) using common household equipment and accessible chemical ingredients.

As an illicit activity, methamphetamine use in New Zealand is difficult to quantify, but it is estimated that in recent years around 1% of the population has used the drug, mostly casually [2]. Drug use surveys among police detainees and frequent users suggest that methamphetamine is readily available [3], and that gangs and professional drug dealers are involved in its supply [4]. Remarkably, methamphetamine appears to be more easy to obtain than cannabis throughout the country [5].

While methamphetamine supply seems to be plentiful, the number of confirmed meth labs detected has been decreasing in recent years. Seventy-four meth labs were identified in 2016, of which 50 were rental properties and four were Housing New Zealand properties [6]. Preliminary data suggest that border seizures of ephedrine, the main precursor used for cooking methamphetamine in New Zealand,[a] have declined. This may reflect a preference for obtaining fully synthesised methamphetamine from overseas rather than manufacturing locally. Nonetheless, small-scale meth labs are still likely to be active throughout New Zealand. These meth labs may be found in residential dwellings, commercial accommodation, and even vehicles.

2.3 Trends in methamphetamine manufacturing

Traditional methamphetamine manufacturing methods involve a range of hazardous (caustic and corrosive) chemicals and solvents. When heated and volatilised during a methamphetamine 'cook', these highly toxic substances can contaminate the immediate area and can be spread through the dwelling [7]. Exposure to such contaminants, either by being present during the production process (and thus possibly inhaling volatile chemicals in the air), or by coming in contact with contaminated surfaces, poses a significant health risk [8, 9].

However, following a number of restrictions on the sale of solvents and certain precursor chemicals, production methods changed in New Zealand. Now the most commonly used methods do not use solvents, and the reaction is mostly performed by distillation with water in contained vessels that do not emit fumes [10].[b] The primary contaminant associated with this manufacturing method is methamphetamine itself.

2.4 Detecting methamphetamine in houses

Techniques originally developed for forensic analysis to identify clandestine meth labs have evolved to a high level of sensitivity that can detect very low levels of the drug and its precursors on surfaces, to aid in the investigation of illicit drug production activity. These techniques have increasingly been used in New Zealand to detect methamphetamine in houses, regardless of whether or not criminal manufacturing activity is suspected, and a thriving industry has arisen to test for the presence of methamphetamine and remediate dwellings where it is found. This industry has until recently been unregulated, with some operators not adhering to appropriate and scientifically sound sampling and clean-up guidelines [13].

The extensive publicity surrounding methamphetamine contamination, along with exaggerated claims about the health risks posed by living in dwellings where residues of the drug can be detected, has led to considerable concern especially amongst tenants, landlords, and potential home buyers and property investors. Evidence of contamination can be placed

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[a] Use of pseudoephedrine as a precursor has not been common in NZ since it was reclassified from a class C to a class B2 controlled drug in 2011, meaning it can only be obtained via prescription.

[b] This method differs from the "one-pot" (also known as "shake and bake") method that is common in the United States, which utilises solvents and potentially explosive combinations of household chemicals typically mixed in a vessel such as a 2 litre soft drink bottle [11]. Burn injuries from exploding bottles are common [12].

in Land Information Memorandum (LIM) reports, which impacts property values. The concerns are compounded by misunderstandings about exposure and risk, leading to an assumption that the presence of any level of residue constitutes contamination that requires remediation.

2.5 Misunderstandings of hazard, exposure and risk

Concerns about methamphetamine exposure in New Zealand appear to be more prevalent compared to other jurisdictions, and likely stem from misunderstandings about the concepts of hazard, exposure and risk.

The risk posed by a hazardous substance (that is, a source of potential harm) depends on how *toxic* it is, and the level of an individual's *exposure* and *sensitivity* to it (Figure 1). For exposure, relevant factors include the amount (or dose) of a substance a person is exposed to, how they are exposed (the route of exposure – for example through the skin, or inhaling or ingesting the substance), and how long they are exposed.

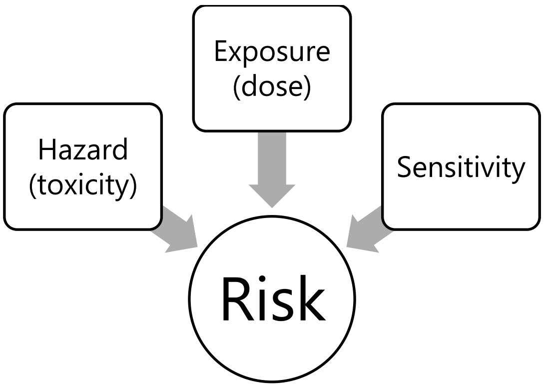

Figure 1: Risk of a hazardous substance is dependent on levels of both environmental exposure and individual sensitivity, as well as the inherent toxicity of the substance.

In this context, two interrelated factors have been mostly absent from the discourse on methamphetamine contamination. The first is the level of methamphetamine found in affected dwellings, which dictates how much exposure a person can have by living there and coming in contact with the affected surfaces. There is widespread misperception that any methamphetamine-related activity in a dwelling, no matter how low the level, results in 'contamination' that has the potential to produce negative health effects. However, generally speaking, the mere presence of methamphetamine does not present a health risk; it only poses a risk if there is a realistic route and duration of exposure, and the doses are high enough throughout this exposure to produce a negative physiological effect.

The second factor is whether the dwelling had been used for methamphetamine manufacture (which may also involve smoking) or for smoking alone. This distinction is about what chemical hazards may be present. Dwellings used for manufacture, depending on the process used, may pose risks from a number of hazardous chemicals and by-products of production of the drug. In contrast, with smoking the potential hazard is methamphetamine itself, residues of which may be deposited on surfaces near where the activity occurred. The risk will be based on whether the levels are high enough to produce physiological effects (and what those effects are) in individuals exposed to them through skin contact or ingestion via hand-to-mouth transfer from contaminated surfaces. These issues are expanded upon in sections 3, 4 and 5.

2.6 New Zealand guidelines and standards

Because of the known risks of exposure to traditional methamphetamine manufacturing chemicals and solvents, guidelines have been developed internationally for cleaning of contaminated premises after a meth lab has been discovered. These guidelines use the detection of methamphetamine below a specified low level *after* remediation as a signal that other contaminants have been sufficiently cleaned away.

In New Zealand, prior to June 2017, the threshold of residue levels at which a dwelling was considered to be 'contaminated' and thus require clean-up, was based on the 2010 Ministry of Health *Guidelines for the remediation of clandestine methamphetamine laboratory sites* [14]. The guideline's cut-off value was 0.5 μg of methamphetamine per 100 cm^2 surface area, which was derived directly from an Australian assessment for meth labs [15], and is considered to be very conservative – there is no evidence that chronic exposure to methamphetamine at levels several times higher than this will lead to adverse health effects. Nonetheless, this guideline provided a benchmark that was then used by the methamphetamine testing industry to signal that testing and remediation was necessary, and led to the belief that even low levels of methamphetamine were potentially dangerous. It began to be used to test large numbers of houses for any traces of methamphetamine. Despite the clean-up guidelines being developed to apply specifically to former meth labs, these types of properties became conflated with properties unlikely to have been used for manufacture, leading to confusion about the appropriate remediation response.

This extension of the use of the 0.5 μg/100 cm^2 level as the acceptable 'threshold' in any situation resulted in numerous properties testing positive for methamphetamine. The efforts of Housing New Zealand to test for methamphetamine and remediate properties exceeding the threshold incurred large expenses and resulted in removal of numerous properties from being available for habitation. Fears aroused by the messages that any detectable level of methamphetamine presented a risk that required remediation may have led to reporting of health affects *believed* to be attributed to methamphetamine contamination.

A New Zealand Standard released in June 2017 [16] adopted a higher – but still conservative – clean-up guideline level of 1.5 μg/100 cm^2, without distinguishing between former meth labs and non-meth lab properties. At the time of writing, this New Zealand Standard has not yet been cited in an Act or Regulation, and is therefore not yet legally enforceable. This report aims to explain why detecting the presence of methamphetamine above a certain level should not be a cause for concern, unless other factors suggest that methamphetamine manufacturing has taken place within the dwelling.

3 Methamphetamine contamination: what's the issue?

3.1 What does methamphetamine contamination really mean?

In New Zealand, the level of concern about 'methamphetamine contamination' has been much greater than that found in other countries. Where in other places the concern is primarily about what is left behind after methamphetamine has been manufactured, here the term has been taken more broadly to concern even very low levels of detectable methamphetamine.[c]

3.2 How does contamination happen and where is it found?

Methamphetamine residue can be deposited on surfaces within dwellings in areas where the drug has been 'cooked' or smoked. These activities lead to methamphetamine becoming aerosolised and spreading away from the immediate area. Methamphetamine can be detected more easily on smooth surfaces such as plastics and metal, compared with more porous materials like wood. However, varnished surfaces collect relatively high levels of residue. Soft furnishings such as carpets, curtains and upholstered furniture absorb residue, but recovery of methamphetamine from these types of surfaces during testing is low [18].

Surface types showing the highest residue levels include (varnished) door frames and ceilings. An analysis of data from a large number of New Zealand properties indicated that floors, on which young children are likely to spend longer hours of contact time, recorded very low levels of methamphetamine – among samples that tested positive, the median level was 0.3 µg of methamphetamine per 100 cm^2 surface area [10].

Methamphetamine residues can be detected on surfaces only at trace levels; the tests used for detection report levels generally in the range of 0.01–1,000 µg/100 cm^2 surface area [19].

3.3 Is contamination different between meth labs and dwellings used for smoking?

Manufacture and smoking have different implications for health risks, because while both result in methamphetamine residue on surfaces, the former activity potentially involves additional risks posed by residues of other hazardous chemicals used in the manufacturing process. The specific range (and levels) of additional contaminants that may be present in the dwelling depends on the method of manufacture and rigour of the process [20], and toxicity assessments on these contaminants have been made [15].

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[c] The Residential Tenancies Amendment Bill (No 2) describes a property as 'methamphetamine contaminated' if *methamphetamine is present in any part of the premises at a level above any prescribed maximum acceptable level* [17].

It is important to note that in recent years, the most common method for methamphetamine manufacture in New Zealand does not involve solvents and is performed using small, purpose built metal cylinders [10]. Various chemical reactions that occur during manufacture are contained within this sealed pressure vessel, which, unlike traditional glassware setups, prevents the release of associated fumes and contaminants. This method of manufacture only releases methamphetamine and very small amounts of various by-products during the later phases of the manufacturing process [10].

Nevertheless, manufacture in general results in greater methamphetamine residue levels than those caused by smoking alone [21]. Experiments involving simulated 'smoking' of methamphetamine found that residue levels decline markedly over a few days [10, 22]. Samples taken soon after a simulated 'smoking' session estimate that a single session may result in levels lower than 0.1 µg/100 cm^2, and multiple sessions, between 1.5 and 5.1 µg/100 cm^2 for up to ~20 sessions [21]. These levels were calculated using conservative measurements, and are likely to overestimate levels arising in practice. The levels detected will also vary by room size, with smaller rooms showing higher levels than larger rooms from the same amount of smoking activity.

Methamphetamine levels that are observed in known former meth labs are substantially higher than those from the simulated smoking samples. Forensic work by the Institute for Environmental Science and Research (ESR) suggests that levels of methamphetamine can be assessed against an 'excessive' threshold that is indicative of manufacturing activity [10]. A US study has reported levels typically higher than 25 µg/100 cm^2 [7], and New Zealand ESR data from 136 meth labs found an average level of 54 µg/100 cm^2 [10].[d] ESR modelling data suggest that in a 20 m^2 room, a very high number of smoke sessions (up to ~1,500) would be required to reach a level of 30 µg/100 cm^2. This estimate may be conservative given that surface residues decrease over time, which is not accounted for in the modelling. Hence, levels around or exceeding 30 µg/100 cm^2 are regarded as strongly suggestive of manufacturing activity.

What does this difference mean for health risks?

Although it is not possible to determine conclusively whether a dwelling had been used for manufacture or only for smoking based solely from the methamphetamine levels found, it is reasonably straightforward to determine the health risks involved. Assuming that the same level of methamphetamine residue has been found in two similar dwellings – one used only for manufacture, and the other only for smoking – then the health risk posed by *methamphetamine itself* is the same in both dwellings.

In theory, a former meth lab may potentially have other contaminants that contribute to the health risk. In cases where there are signs of traditional manufacturing activity, these may be of concern if high levels of methamphetamine contamination indicate that cleaning has not been carried out. However, since methamphetamine levels are considered a marker for the levels of other potential contaminants, a former meth lab containing low levels of

[d] Further New Zealand data are available from ref [18] which reports levels from 20 suspected clan labs, although interpretation is limited because most sites were cleaned prior to sampling.

methamphetamine is also likely to contain low levels of other associated substances. Furthermore, the manufacturing methods most often used in New Zealand now mostly involve solvent-free distillation in sealed vessels that minimise contaminant spread, although methamphetamine is released (along with low levels of minor by-products) in the 'salting out' phase. The use of methods involving toxic metals such as lead and mercury has not been reported in New Zealand [10].

Hence *from a health risk perspective*, if methamphetamine levels are low, it is likely to be immaterial whether a dwelling was used as a meth lab or not. The relevance of distinguishing between the two types of dwellings is mostly relevant for forensic and law enforcement purposes.

4 Establishing health-based standards for methamphetamine exposure

A health-based risk assessment is a process used to estimate the nature and probability of adverse health effects in people who may be exposed to chemicals in the environment. Such assessments start with a *toxicological characterisation* of the substance to establish whether it has the potential to cause harm (is it a hazard?), and if so, under what circumstances. This involves determining the numerical relationship between exposure to the substance and any resulting health effects, known as a dose-response assessment. After this, *exposure assessments* are conducted to identify the extent to which the exposure actually occurs. All of this information feeds into a *risk characterisation*, which forms a conclusion about the nature and the size of the risk, and whether additional risk management measures are needed. This section discusses how health-based standards were derived for methamphetamine (summarised in Figure 2).

4.1 Toxicity assessments

We know that methamphetamine has the potential to cause harm (as do most chemicals if the exposure is high enough) – but at what doses or exposures would this occur? The aim of a toxicity assessment is to establish the relationship between an adverse effect of a substance (the harm it causes) and the dose (the exposure level) at which it takes place. Then, a threshold 'dose' can be calculated to indicate either *the dose that would have no effect* on human health, or *the lowest dose at which an effect might be observed*. This difference in how the threshold dose is defined is important, as it can lead to very different thresholds being calculated.

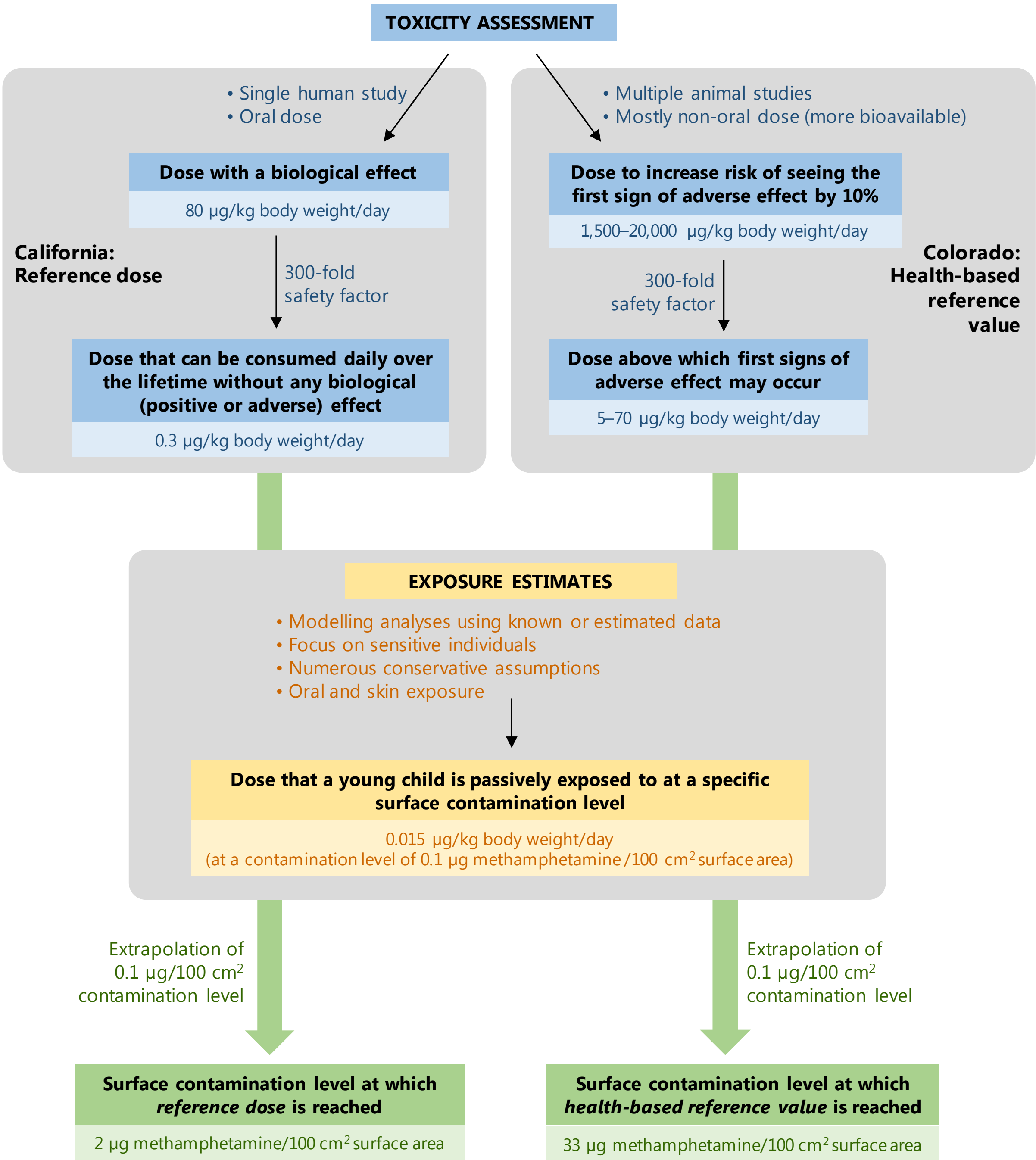

Figure 2: A highly simplified diagram showing the process of deriving health-based standards for methamphetamine. The exposure estimate for a young child, derived from New Zealand ESR modelling data, is based on a hypothetical surface concentration of 0.1 micrograms (µg) methamphetamine per 100 cm^2 surface area. (Separate modelling analyses by California and Colorado [not shown] also used a level of 0.1 µg/100 cm^2 in their calculations. This selection was somewhat arbitrary as it was based on an early, non-health based clean-up standard adopted by the state of Washington.) The units µg/kg body weight/day refer to an ingested amount of methamphetamine measured in µg per kilogram (kg) of body weight per day. These doses represent a daily intake level that is protective (by a 300-fold safety buffer) against any effect (in the case of the reference dose) or against a 10% increased risk of the first signs of an adverse effect (in the case of the health-based reference value).

Toxicity assessments on methamphetamine have been undertaken independently by the US states of California [23] and Colorado [24, 25], for the purpose of establishing a risk-based remediation standard for methamphetamine. California developed a threshold 'reference dose' (RfD), which is a formal toxicological measure that estimates *the amount of a substance that humans (including children and other sensitive groups) can be exposed to daily, over their lifetime, without any harmful effects*. Because there are no data to suggest that low doses of methamphetamine are toxic in humans, the assessment was based on a single clinical study of methamphetamine used as a weight control therapy in pregnant women in order to have a starting point from which to measure any dose effects [26]. The lowest dose that exhibited *any* effect in this study was 5,000 µg per day (equivalent to 80 µg/kg body weight/day for the average woman). Incorporating a large safety factor to ensure that there would be no possibility of an effect in even the most sensitive individual, the RfD was calculated to be **0.3 µg/kg body weight/day** [23]. It means that an individual who may be especially sensitive to methamphetamine, such as a small child (10 kg) or a woman of childbearing age (70 kg), can respectively consume 3 µg or 21 µg of methamphetamine every day for the rest of their lives, without ill effect.

In contrast, Colorado developed a health-based reference value, which indicates *the lowest dose that humans (including children and other sensitive groups) can be exposed to at which the first onset of any adverse health effect may occur*. This value is distinct from a RfD, which by definition is more conservative. The reference value was calculated, based on a number of animal toxicology studies, as **5–70 µg/kg body weight/day** (it is expressed as a range to reflect the different results from the body of studies assessed) [24, 25]. Calculating from the more conservative end of this range, the lowest dose at which there is a potential for an adverse effect would be 50 µg of methamphetamine daily for a 10-kg child, or 350 µg daily for an adult weighing 70 kg.

A comparison of the two assessments, summarised in Table 1 and further described in Appendix 8.1, shows that the California-derived reference dose is more conservative than the Colorado health-based reference value by a factor of between 17 and 233 (depending on which end of the range – 5 or 70 µg/kg body weight/day – is taken). This means that Colorado's assessment allows for at least 17 times the amount of methamphetamine to which a sensitive individual can be exposed. This marked difference mainly reflects the difference in how safety has been defined (i.e. level with no appreciable risk vs lowest level at first possible adverse effect), and these definitions have in turn been informed by very different types of studies (one primary human study vs multiple animal studies). It is therefore not possible to give primacy to one assessment over the other, but it should be emphasised that both assessments incorporate very conservative assumptions and a very large (~300-fold) safety factor.

Table 1: Summary of methamphetamine toxicity assessments

	California (OEHHA)	**Colorado (CDPHE)**
Measure of toxicity	Reference dose	Health-based reference value
Definition	The dose at or below which adverse health effects are unlikely to occur	Lowest dose at which an adverse effect may occur
Study population and effects	Reduced weight gain in pregnant women	Developmental and reproductive toxicity in laboratory animals
Calculated dose (µg/kg body weight/day)	0.3	5–70

These values can also be placed in perspective by comparison with the recommended doses for therapeutic purposes (Figure 3).

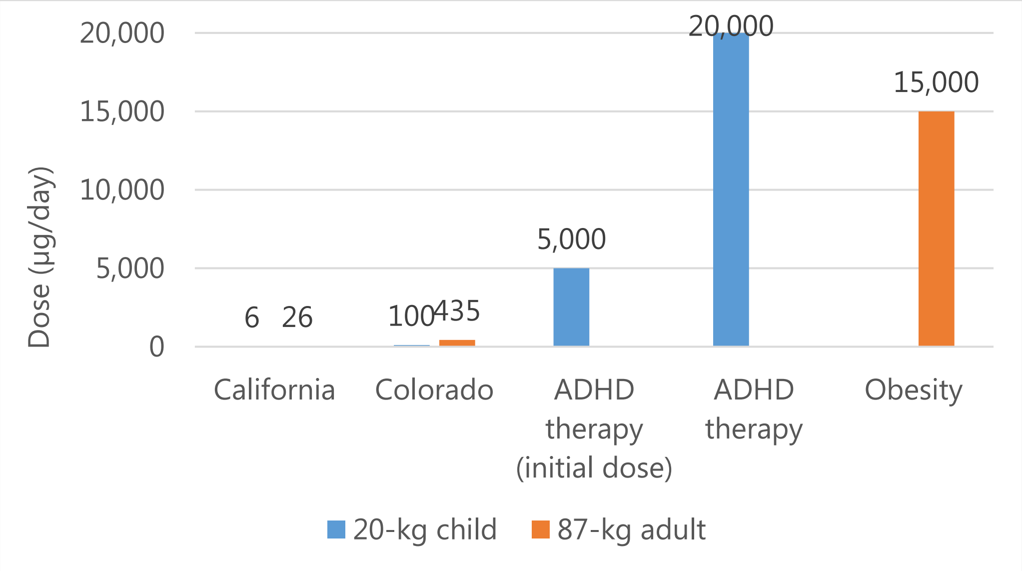

Figure 3: Therapeutic daily doses for ADHD treatment in a six-year-old child of average weight, or for obesity treatment in an adult, compared with the maximum daily exposure doses indicated for these two individuals by the California and Colorado guidelines. The lower end of the recommended ADHD therapy dose (20,000 µg/day) for a six-year-old child is shown. Obesity treatment dose assumes that three meals are consumed daily. The exposure doses calculated from the California and Colorado guidelines in this figure are higher than those referred to in-text; this is because this figure relates to individuals undergoing methamphetamine treatment, rather than the sensitive groups of infants and non-obese adult women, who would have lower body weight.

Treatment of children six years and older for ADHD symptoms begins at 5,000 µg and increases to about 20,000–25,000 µg daily, while treatment of adults for obesity involves 5,000 µg per meal over a few weeks. As with most medications, therapeutic use of methamphetamine may involve side effects such as headaches and appetite loss, though it is not known how common these effects are [27].

4.2 Estimating passive exposure doses to establish remediation guidelines

This section briefly describes how various jurisdictions have estimated the exposure doses of sensitive individuals to methamphetamine in remediated dwellings, and how these estimates were used to establish remediation guidelines. It is important to note that all the guidelines (except the New Zealand ESR report [28], as discussed later) have considered methamphetamine residues only in former meth labs, and that residues arising from smoking alone have not been considered.

Each agency used different mathematical models to estimate methamphetamine exposure doses. The models take numerous factors into account, such as the type of surface containing the residue (hard floors or carpets), the way exposure to residues might occur (through skin on hands and body, or through ingestion from a child's 'mouthing' activity with toys and fingers), and how frequently the dermal contact or mouthing activity might occur in scenarios that assume *maximum possible* exposure. Where such data were not available, best estimates from a conservative standpoint were used.

- California found that, in order not to exceed their previously determined reference dose of 0.3 μg/kg body weight/day for a child aged 1–2 years old, the surface concentration of methamphetamine should be no higher than **1.5 μg/100 cm^2** [29].[e]
- Colorado analysed 3 proposed remediation standards: 0.05, 0.1, and 0.5 μg/100 cm^2. Their modelling found that for an infant, a 6-year-old child, and a woman of childbearing age, a standard of **0.5 μg/100 cm^2** led to exposure doses well below the health-based reference value of 5–70 μg/kg body weight/day .[f]
- In Australia, the government adopted a value of **0.5 μg/100 cm^2** as a clean-up guideline [30] – this was based on a risk assessment report that modelled estimated doses against California's reference dose [15].[g]

New Zealand risk assessment

In 2010, the New Zealand Ministry of Health published a remediation guideline of **0.5 μg/100 cm^2** for former meth lab dwellings [14]. This was directly taken from the Australian risk assessment report in lieu of a separate assessment.

A 2016 ESR report [28][h] commissioned by the Ministry of Health has since proposed a New Zealand-specific set of remediation standards. It estimated the total exposure doses for a

[e] The model also showed that the most important factor in determining overall exposure dose was the fraction of methamphetamine that is transferred from surface to skin.

[f] Remediation standards higher than 0.5 μg/100 cm^2 were not assessed.

[g] This guideline is more conservative than that adopted by California, despite use of the same reference dose. The risk assessment report attributed this to use of a less complex model to estimate exposure doses, as well as use of more conservative estimates.

[h] This report provided an up-to-date review of the scientific and 'grey' literature on methamphetamine, evaluated the remediation guidelines from other jurisdictions, and presented modelling work estimating exposures for the New Zealand population. It differs from other assessments by providing guidelines

young child and for an adult woman (through whom a fetus may become exposed). The report also modelled the exposure doses in houses with and without carpets. In order not to exceed the California reference dose, the following clean-up levels were recommended:

- **2 µg/100 cm²** for non-carpeted dwellings that have not been used for manufacture.
- **1.5 µg/100 cm²** for carpeted houses not used for methamphetamine manufacture. The level is lower because carpeted floors lead to higher exposure doses.[i]

Although in theory the above guidelines are appropriate for remediated houses regardless of whether they had been used for manufacture or smoking, the report acknowledges that former meth labs carry an additional risk of other contaminants that may have been undetected or not adequately removed during clean-up. Therefore, as a precautionary measure, the report recommended the considerably more conservative guideline of **0.5 µg/100 cm²** for dwellings previously used for methamphetamine manufacture.

The rationale is that lower levels of methamphetamine are likely to indicate lower levels of other chemicals. Thus, this lower level should not be interpreted as methamphetamine *per se* posing a greater risk in a former meth lab. In theory, and according to the report's guidelines, a test result showing a level of 0.5–2.0 µg/100 cm² in a known former meth lab would be considered to pose no health risk from methamphetamine itself.[j]

4.3 The New Zealand standard

In June 2017, Standards New Zealand published a standard on the testing and decontamination of methamphetamine-contaminated properties (NZS 8510:2017).[k] The standard does not focus on risk assessment or health effects, but the selection of a clean-up level was informed by the 2016 ESR report. On the basis of this report and public submissions, a single remediation level of **1.5 µg/100 cm²** was chosen, irrespective of whether the dwelling had been used for manufacture or smoking, or whether carpets are present or not. Table 2 summarises the chosen remediation values by each agency.

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for both non-carpeted and carpeted dwellings, and also distinguishing between dwellings previously used by methamphetamine smokers or by methamphetamine manufacturers.

[i] California also include carpeting in their model, but only the single guideline of 1.5 µg/100 cm² is provided.

[j] The ESR report proposed that screening for lead and mercury, which are heavy metals that can accumulate in the body, should be undertaken in dwellings formerly used as clan labs. However as current manufacturing methods in New Zealand do not use these components [10], they are no longer considered to pose a risk unless deemed otherwise by a forensic investigator (J Fowles, report co-author, *pers comm*, 20 March 2018), or unless production methods change to include these components (C Nokes, ESR, *pers comm*, 20 March 2018).

[k] The purpose of this standard was to provide best practice guidelines to accurately sample and effectively decontaminate affected dwellings, and to ensure that methods for testing are reliable. The wider aim was to ensure that a dwelling previously used to manufacture or smoke methamphetamine is safe for subsequent occupants.

Table 2: Guidelines for maximum methamphetamine levels in remediated dwellings. Note that Australia and ESR based their assessments on California's more conservative reference dose.

			California	Colorado	Australia	NZ (ESR)	NZ Standards
Guideline (µg/100 cm^2)	Former meth lab		1.5	0.5	0.5	0.5	1.5 (3.8 for low-use areas)
	Non-meth lab	Carpeted	-	-	-	1.5	
		Non-carpeted	-	-	-	2.0 (3.8* for adult woman)	

** This value is higher than that for young children due to greater body weight and an assumed absence of exposure via oral ingestion.*

4.4 Comparison of the guidelines

Despite the variation in recommended remediation levels (Appendix 8.2), all of the described guidelines are risk-based, meaning they take into account the toxicity of methamphetamine as well as the potential levels of exposure to it.

There are two important points to be noted about all of the remediation guidelines as a whole. First, from a health perspective, none should be interpreted as a specific 'threshold' that if exceeded – and particularly by a small margin – is likely to result in an adverse effect. The second point is that *all* of the guidelines can be considered to be very conservative as they are deliberately based on factors assuming 'worst case' scenarios that are unlikely to reflect a real-world situation (Appendix 8.3). It should also be noted that methamphetamine does not accumulate in the body,[l] and animal studies suggest that the effects in the brain from single or short-term exposure to a high dose may be reversible [33].

4.5 Alternative calculations of risk levels

The ESR report calculated clean-up guidelines based on the level at which the *California RfD* would not be exceeded. However, the ESR exposure data can also be used to calculate the maximum residue level for exposure that would ensure the *Colorado's health-based reference value* will not be exceeded.[m] This calculation gives a maximum acceptable contamination level of **33 µg/100 cm^2** for dwellings without carpets, and **23 µg/100 cm^2** for carpeted dwellings (Table 3).

[l] The time taken for half of an orally ingested dose of 10–20 mg methamphetamine to be cleared from the body (the 'half-life' – used in pharmacology to indicate how quickly a drug is eliminated) is about 10 hours [31], Within 24 hours, about 70% of the dose is excreted in urine [32].

[m] J Fowles, *pers comm* via C Nokes, 1 March 2018.

Table 3: The relationship between surface methamphetamine contamination levels and exposure doses for a 1–2 year old child in (a) non-carpeted properties, and (b) carpeted properties. This relationship was scaled up in a linear manner to calculate the surface level at which a dose of 5 µg/kg body weight/day (i.e. Colorado's health-based reference value) is reached. Surface levels are given to one decimal place.

(a) Non-carpeted properties

Surface contamination level (µg/100 cm^2)	**Exposure dose for a 1–2 year old child (µg/kg body weight/day)**	**Notes**
0.1	0.015	Exposure dose calculated by ESR
0.7	0.1	Extrapolated data to demonstrate relationship
1.3	0.2	
2.0	0.3 (California's RfD)	Surface level calculated by ESR
33.3	5 (Colorado's health-based reference value)	Surface level calculated in this report

(b) Carpeted properties

Surface contamination level (µg/100 cm^2)	**Exposure dose for a 1–2 year old child (µg/kg body weight/day)**	**Notes**
1.4*	0.3 (California's RfD)	Surface level calculated by ESR
4.7	1	Extrapolated data to demonstrate relationship
9.3	2	
23.3	5 (Colorado's health-based reference value)	Surface level calculated in this report

** J Fowles, pers comm via C Nokes, 1 March 2018*

These figures – 33 and 23 µg/kg body weight/day – indicate levels above which an adverse health effect may be observed; in other words, lower levels are unlikely to have health impacts. Notably, even though they still include a 300-fold safety buffer, these figures are 15–22 times as high as that adopted by Standards New Zealand (see Figure 2).[n]

A similar exercise extrapolating the calculated contamination level based on Colorado's exposure data and its own health-based reference value can likewise be performed (Appendix 8.4).

[n] Toxicological assessments generally incorporate safety buffers to account for uncertainties where robust data are not available. In theory, with the omission of the 300-fold safety buffer, the surface contamination levels at which a young child would be exposed to Colorado's health-based reference value of 5 µg/kg body weight/day are 10,000 µg/100 cm^2 and 7,000 µg/100 cm^2 for non-carpeted and carpeted properties, respectively.

5 Are there health risks from passive methamphetamine exposure?

The health risks posed by methamphetamine depend primarily on the type and level of exposure (Figure 4). The adverse effects of first-hand exposure – that is, its use involving smoking, ingesting or injecting large doses over a prolonged period, are well documented [34, 35].

There are also reports of ill-health associated with second-hand exposure via residing in a dwelling concurrently or previously used as a meth lab [9, 36]. The drug can be detected in hair of exposed children [37], in whom behavioural problems are common [9], although the latter finding may be confounded by other social factors. Less is known about the effects of breathing in second-hand smoke arising from methamphetamine use, and the US National Institute on Drug Abuse notes that available evidence for adverse health effects of second-hand exposure is currently lacking [38].

In contrast to the known effects of first-hand exposure, no data have been reported relating to third-hand exposure situations, which affect a greater majority of the population – that is, non-users living in dwellings (whether remediated or not) that had been previously used only for smoking of methamphetamine (Figure 4). To the best of our knowledge there is currently no available evidence in the scientific or grey literature that low-level methamphetamine exposure, involving levels that may be encountered from skin contact or oral ingestion of residues on household surfaces, poses a health risk in humans. Realistic scenarios of exposure through contact with surface residues, even for toddlers who often put their hands in their mouths, do not suggest that levels would reach close to a threshold where adverse effects would be observed.

Under the Health Act 1956, "poisoning arising from chemical contamination of environment" is a notifiable disease [39]. This includes methamphetamine poisoning. Since 2013 a national register monitoring diseases, injuries and illnesses from hazardous substances has been maintained.[o] Between 2014 and 2016, two cases of food poisoning (from the same household) were attributed to methamphetamine intake via a contaminated container [40].[p] No other confirmed cases have been reported.

[o] This surveillance system is undertaken by Environmental Health Indicators New Zealand (EHINZ), Massey University, on behalf of the Ministry of Health.
[p] Additional details provided by D Read, EHINZ, *pers comm*, 4 April 2018.

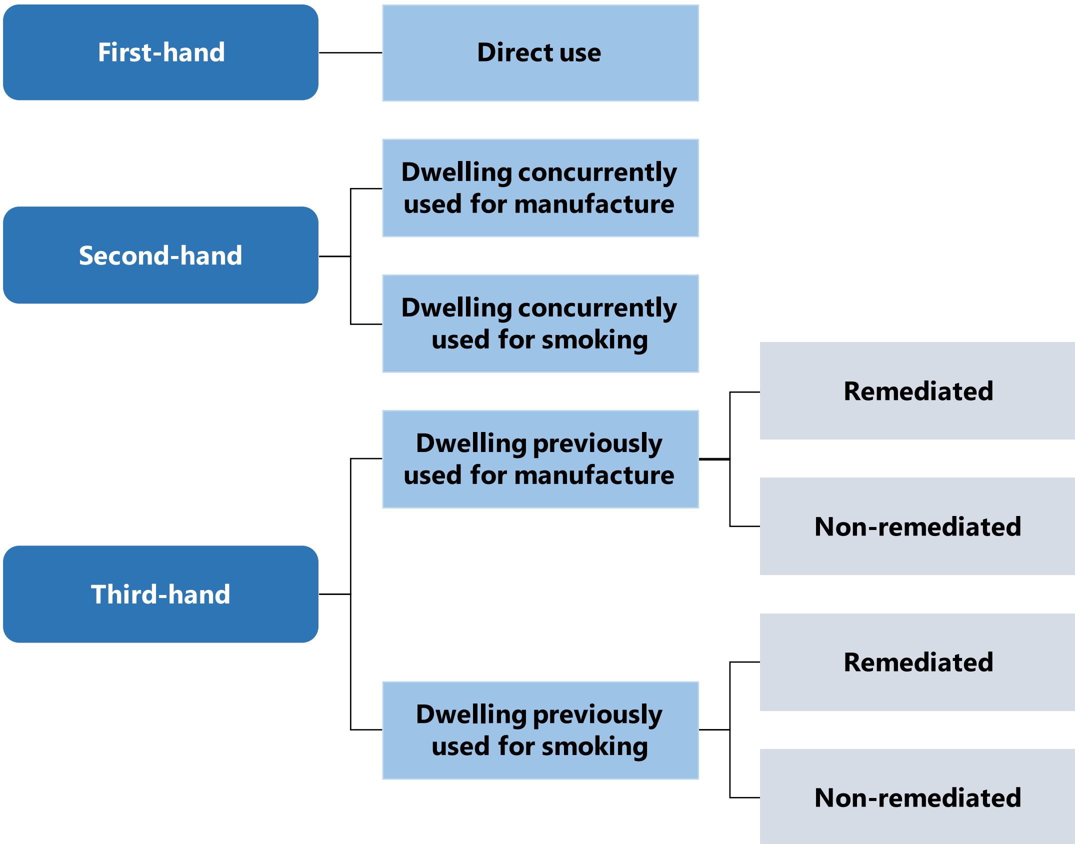

Figure 4: Methamphetamine exposure pathways. Note these are not mutually exclusive.

The Ministry of Health also notes that there have been no recorded cases in New Zealand of poisoning or injury arising from residing in dwellings that had been previously used for manufacture or use of methamphetamine.[q] While there have been some anecdotal reports of minor ill effects associated with such dwellings, as publicised in the media, there are no reports on whether these cases have received a formal medical diagnosis, or had their causes attributed. Furthermore, the reported symptoms (e.g. asthma, skin rashes) are diverse and generally not known to be physiological effects of methamphetamine. The contribution of other common factors known to affect health, such as dampness and mould, or other chemical exposures in houses, has not been examined and may be equally or more likely explanations of the diverse symptoms claimed. Reporting of such effects to public health services appears to have declined following the introduction of the new standard (NZS8510:2017),[r] with its higher 'contamination threshold' for a property requiring cleaning. This suggests that a significant proportion of the reports prior to this were based mainly on the *perception* that low levels of methamphetamine were dangerous.

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[q] S Gilbert, Ministry of Health, *pers comm*, 21 Feb 2018. The Ministry has not received any notifications of poisoning arising from chemical contamination of the environment under the Health Act 1956, or of hazardous substances injuries under the HSNO Act due to exposures to methamphetamine contaminated dwellings.
[r] D Barnfather and J Whitmore, Auckland Regional Public Health Service, *pers comm*, 21 March 2018.

There is currently very limited toxicity data that can inform the assessment of long-term environmental exposures to methamphetamine residues. Methamphetamine is not considered to have high intrinsic toxicity – if so, it could not be used as a therapeutic drug for ADHD and obesity. It is not listed in hazardous substances registries such as the ATSDR (Agency for Toxic Substances and Disease Registry), an extensive database run by the US Centers for Disease Control and Prevention (CDC). However, some substances that are not toxic at low doses can accumulate in the body, causing adverse effects over time. Although there are cumulative effects from high-dose, long-term methamphetamine use, the chemical itself does not stay in the body or accumulate to higher levels. Ingested methamphetamine is generally eliminated from the body within about a day. This means that doses or exposures that do not have an effect in the short term are not cumulative, and theoretically should not lead to any long-term harm. It should also be noted that residue levels on household surfaces also diminish over time, so a person is not exposed to a constant dose every day.

A study of prenatal drug exposure in New Zealand children in which exposure to methamphetamine, alcohol and/or marijuana was verified objectively by meconium analysis (i.e. the drugs were detected in the first faeces of the newborn infant) concluded that, unlike alcohol, prenatal exposure to methamphetamine did not affect function of the visual cortex, an area of the brain thought to be particularly vulnerable to abnormal neurodevelopment [41]. The children in that study were assessed at 4.5 years of age. A related study observed subtle effects on fine-motor performance at 1 year that mostly resolved by 3 years of age [42]. These children were exposed *in utero* to much higher levels of the drug than would be possible from third-hand exposure of the mother to methamphetamine residues on household surfaces.

Indeed, animal studies suggest that chronic low-dose[s] methamphetamine *promotes* brain cell development and function [43], and improves outcomes following severe traumatic brain injury [44, 45]. Clinical studies in humans with brain injury, involving multiple doses of 5,000–100,000 µg D-amphetamine (a related drug with similar effects), have not reported any adverse effects associated with the drug itself [46].

6 Towards an evidential and health risk-based approach for managing potential exposure and contamination

Risk is a combination of the likelihood of a negative event happening (such as coming into contact with a level of methamphetamine that would produce an adverse effect), and the consequence of that event happening (what the effects are, and how serious they are). A risk-based approach to managing methamphetamine contamination means that actions taken to mitigate the potential health risks are proportionate to the level of risk.

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[s] Rodents are less sensitive than humans to methamphetamine, and therefore higher absolute doses are required to observe health effects. Thus the doses used in these studies are considered to be 'low' in the context of animal research.

6.1 Risks in perspective

When considering how to determine whether a risk is high enough to warrant substantial remediation measures, it sometimes helps to compare the risk to other similar risks, and consider how they are dealt with (or not) in society. For example, we do not test for or regulate 'third-hand smoke' residues from cigarettes, which contain carcinogenic polycyclic aromatic hydrocarbons such as benzopyrene, as well as nicotine, which are measurable on indoor surfaces months after the last smoke [47, 48]. Similarly, other household hazards such as mould, lead paint and asbestos pose greater health risks than third-hand methamphetamine exposure (at least in a non-meth lab environment).

There is evidence in some New Zealand communities that methamphetamine residue can be detected on banknotes [49, 50], and occasionally at levels close to that found in many houses currently testing 'positive' and deemed to be in need of remediation.

6.2 Is the current approach in New Zealand commensurate with the risk?

What we know from the preceding discussion is that the likelihood of being exposed to enough methamphetamine on household surfaces to absorb (through the skin or via hand-to-mouth activities) a quantity that would have a physiological effect is extremely low, even in young children. Considering the available evidence, the perception of the risk and the reaction to it in New Zealand has been disproportionate.

New Zealand appears to be unique with regard to its approach to the issue of methamphetamine contamination of residential properties. While other countries and jurisdictions have also established standards for remediation of premises where clandestine meth labs have been identified, these standards are for the most part not used for guiding clean-up of dwellings where no manufacture has taken place. Some states in the US issue only practical guidelines for cleaning a known (former) meth lab, and do not require testing for methamphetamine levels [51].

The international guidelines use methamphetamine as a marker for the presence of other contaminants, recognising that these chemicals and solvents are the main hazards associated with clandestine laboratories. The range and levels of contaminants vary widely among meth labs, making it difficult and costly in practice to test for every single potential contaminant that may remain after clean-up. It is for this reason that an extra conservative guideline is specifically used for former clandestine labs, where lower levels of remaining methamphetamine are assumed to indicate lower levels of other contaminants. This does not imply that methamphetamine itself poses a greater health risk in former labs.

The trends in methamphetamine manufacturing in New Zealand mean that lab activity is no longer always obvious in a dwelling. But this also means that in general, common production methods result in less environmental contamination, and the main contaminant associated with any methamphetamine-related activity is the drug itself. Nonetheless, the methamphetamine testing and decontamination industry has promoted the idea that all properties are potentially in danger from methamphetamine contamination [52].

A study by ESR of ~1,600 New Zealand public sector residential properties that were suspected to have methamphetamine contamination can provide a general idea of the range of methamphetamine levels that may be found in affected dwellings [10]. Of the total number of properties tested, approximately two thirds showed some detectable levels of methamphetamine. These dwellings by definition represent a biased sample with higher potential for methamphetamine contamination, being rental accommodation, and considering that in most cases the landlord or agency had 'reasonable cause' to suspect methamphetamine use. The data are therefore likely to significantly overestimate the extent of the problem in the wider New Zealand housing stock. The data show that out of more than 13,000 surface samples taken, over 75% had methamphetamine levels under 1.5 µg/100 cm^2, and approximately one third were negative. The average level in positive samples was 2.7 µg/100 cm^2. Thus, smoking-related levels, although generally exceeding the NZ standard clean-up level, are still very low.

Less than 1% of the samples in the ESR dataset tested above 30 µg/100 cm^2, suggesting a low prevalence of properties potentially used for manufacture. Even then, toxic compounds such as lead and mercury that are typically used in traditional production methods have not been found in meth labs in New Zealand.

6.3 Implications for methamphetamine screening and remediation

Given the low probability of encountering high levels of methamphetamine in properties where meth lab activity is not suspected, and also considering the very conservative nature of the standards with respect to the risks of adverse effects from third-hand exposure to methamphetamine, a risk-based approach suggests that the guideline of 1.5 µg/100 cm^2 should not be universally applied.

Remediation is certainly warranted if high levels of methamphetamine are present that are indicative of manufacturing activity or excessive smoking. Levels >30 µg/100 cm^2 are considered by forensic experts to signify that manufacture is likely to have taken place [10]. Testing for lower levels that still suggest relatively high levels of smoking (e.g. >15 µg/100 cm^2) could be used to identify specific areas of contamination that warrant remediation. Remediation includes removal of all potentially contaminated porous materials or items (furnishings, carpets) and cleaning of the contaminated surfaces, using the NZS 8510:2017 standard as a guide.

Where lower levels are detected, remediation is often not justified. However, as low levels cannot definitively rule out manufacture, remediation down the 1.5 µg/100 cm^2 standard may be prudent if there is also sound *reason to suspect previous meth lab activities*. This would only be as a precautionary measure to remove other toxicants that may be present but not measured.

With regard to making screening of properties commensurate with the possible risks, some specific aspects require consideration:

Problems with field composite screening

Combining multiple samples taken throughout a dwelling into a single composite sample, as permitted in NZS 8510:2017, has limited value and cannot accurately reflect levels of risk, and depending on how the data are integrated can lead to quite misleading interpretation and false impressions of high exposure. This approach of composite analysis is promoted as a cost-effective option for initial screening, but it is in fact costly because it creates a bias towards detecting higher levels, and can falsely impose a requirement for further testing without identifying the areas (nor the actual levels) of potential contamination.

Given the low health risk in properties that were not used as meth labs, if they are to be tested, the initial screening should not involve composite field testing that could produce a false positive result – that is, detecting a level of 1.5 µg/100 cm^2 (or slightly above) from a composite field sample that adds the readings from all swabs together. Such field composite testing means that every sample can be below the standard, but when combined can raise the overall result, triggering another round of expensive testing.

Recommendations for risk-based assessment of properties

- Testing for methamphetamine in residential properties should not be the default pathway. From a risk perspective, testing is only necessary where meth lab activity is suspected or where very heavy use is suspected.
- Composite field testing – that is, combining the readings from multiples swabs and adding them together to make a determination of 'contamination' if they exceed the 1.5 µg/100 cm^2 standard – should not be used.
- There is merit in using tests that rapidly provide a simple positive or negative result in multiple locations for detection of higher levels on site, followed by sensitive testing in targeted areas that produce a positive signal. For example, National Institute for Occupational Safety and Health (NIOSH)[t]-validated colourimetric tests are available in the US that detect levels >15 µg/100 cm^2 [53, 54]. If methamphetamine is not detected at this level anywhere within a property, there is little cause for concern unless there are other reasons to suspect methamphetamine manufacturing activity. If the screening test shows levels >15 µg/100 cm^2, then a more thorough assessment should be conducted to determine whether there is an area of high contamination that needs to be remediated.
- Where a former meth lab has been identified, remediation should continue to current guidelines as outlined in the NZS 8510:2017 Standard.

Further considerations and next steps

This report is intended to contribute to a discussion about an appropriate approach to managing properties affected by methamphetamine in a manner that is commensurate with

[t] NIOSH is a research agency within the US Centers for Disease Control and Prevention that studies worker safety and health. The NZS 8510:2017 Standard requires that methamphetamine testing follows NIOSH-validated methodologies.

the risks to individual property owners, tenants, and New Zealand as a whole. Several areas need to be considered further:

- The validation of rapid tests for use in New Zealand that are accurate for detection of contamination at levels higher than the current standard is critical if the above recommendations are to be utilised. The recommendations are based on an available test with a detection level of 15 µg/100 cm^2, but other rapid tests and methodologies could potentially be validated with detection levels below this (e.g. 5–10 µg/100 cm^2), which would be equally useful as screening tools to detect only areas of relatively high contamination.
- More work is needed to develop guidelines around what constitutes a reasonable suspicion of the presence of a former meth lab, taking into account the changing environment of manufacturing. Similarly, a clearer definition of what constitutes 'excessive use', and how this is reflected in contamination levels, is warranted. ESR is currently undertaking important work in these areas.
- Guidelines are needed to support landlords in creating operational procedures and policies.
- Accreditation of testers is needed to ensure testing protocols can be trusted to return consistent and scientifically supportable results.

7 Conclusions

There is currently no evidence (in either humans or animals) that the levels typically resulting from third-hand exposure to methamphetamine smoking residues on household surfaces can elicit an adverse health effect. We note, however, that *absence of evidence* is not *evidence of absence* of an effect. There is a clear need for more research and a co-ordinated inter-agency effort to build up a robust dataset.

Toxicity assessments and exposure dose models used to establish standards for remediation of former meth labs (which are used in the NZS 8510:2017 to guide remediation, and do not distinguish between manufacture and use) have deliberately adopted conservative assumptions, with large (~300-fold) safety margins built in. These margins reflect data gaps and uncertainties in the calculations and are considered precautionary.

Taken together, these factors indicate that methamphetamine levels that exceed the NZS 8510:2017 clean-up standard of 1.5 µg/100 cm^2 should not be regarded as signalling a health risk. Indeed, exposure to methamphetamine levels below 15 µg/100 cm^2 would be unlikely to give rise to any adverse effects. This level still incorporates a 30-fold safety buffer on a conservative estimate of risk.

Testing for low levels of methamphetamine in residential properties in New Zealand has come at a very high cost. Although promoted as being protective of human health, the actions taken in pursuit of zero risk (which is not achievable in any case) have been disproportionate to the actual health risks. Trade-offs need to be considered, particularly within social housing, where the risk of being in an unstable housing situation is likely to be far greater than the risk of exposure to low levels of methamphetamine residues. There have been huge costs to homeowners, landlords, and the state – not only of testing and remediation itself, but the unnecessary stigma of ‘contamination’ (for example on a LIM report), often based on little or no actual risk.

It is important that guidelines for mitigation measures are proportionate to the risk posed, and that remediation strategies should be informed by a risk-based approach. This means that, because the risk of encountering methamphetamine on residential surfaces at levels that might cause harm is extremely low, testing is not warranted in most cases. Remediation according to the NZS 8510:2017 standard is appropriate only for identified former meth labs and properties where excessive methamphetamine use, as indicated by high levels of methamphetamine contamination, has been determined.

8 Appendix

8.1 Establishing threshold doses for methamphetamine

California: Reference dose

To review the toxicity of methamphetamine, the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA) relied primarily on human studies [23]. From the available literature, a study on pregnant women who were given methamphetamine to control weight gain was used to calculate the RfD [26]. This is a 1961 placebo-controlled, double-blind study that involved relatively small sample sizes and did not provide statistical analyses. However its findings were corroborated by another similar but smaller study [55]. While weight change does not necessarily reflect an 'adverse' health outcome, it gives an indication of dose levels at which physiological effects can be observed. The drug was given in a sustained release formulation (the same as that used for ADHD therapy), which is thought to best mimic the continuous exposure potentially experienced within a contaminated dwelling.

Using the study data, the OEHHA determined that the lowest dose resulting in an observed effect on weight gain was 5,000 µg/day (equivalent to 80 µg/kg body weight/day for the average woman). Guided by other scientific literature on the effects of methamphetamine, the OEHHA further applied widely accepted uncertainty factors to this value, resulting in a reference dose of 0.3 µg/kg body weight/day.

It is important to note that an RfD focuses on *absence* of *potential* for harm, and over the long term. Thus, exceeding the dose even over an extended period is unlikely to result in an adverse effect. Furthermore, this level is orders of magnitude lower than the doses that are prescribed for therapeutic purposes (see Figure 3).

Colorado: Health-based reference value

The Colorado Department of Public Health and Environment (CDPHE) reviewed multiple laboratory animal studies on the developmental and reproductive effects of methamphetamine exposure [24, 25]. They calculated that the dose at which a 10% extra risk of the effect can be observed in exposed animals compared to control animals is 1,500–20,000 µg/kg body weight/day. After applying conservative uncertainty factors, a health-based reference value of 5–70 µg/kg body weight/day was determined. The lowest end of this range was derived from a single study showing decreased fetal weight in mice [56]. This study intravenously administered 5,000 or 10,000 µg/kg body weight/day methamphetamine to pregnant mice for 3–7 days. Decreased fetal weight was observed in all treatment groups. From this, the CDPHE calculated a benchmark dose level (BMDL)[u] of 1,500 µg/kg body weight /day. Applying a safety factor of 300 yields a value of 5 µg/kg body weight/day.

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[u] For this assessment, the BMDL was taken as the dose associated with the 95% confidence interval around the BMD_{10} (the dose associated with a 10% effect).

Figure 5 compares the relative estimated doses for a typical young child and an adult woman that would be reached at the California RfD and Colorado health-based reference value.

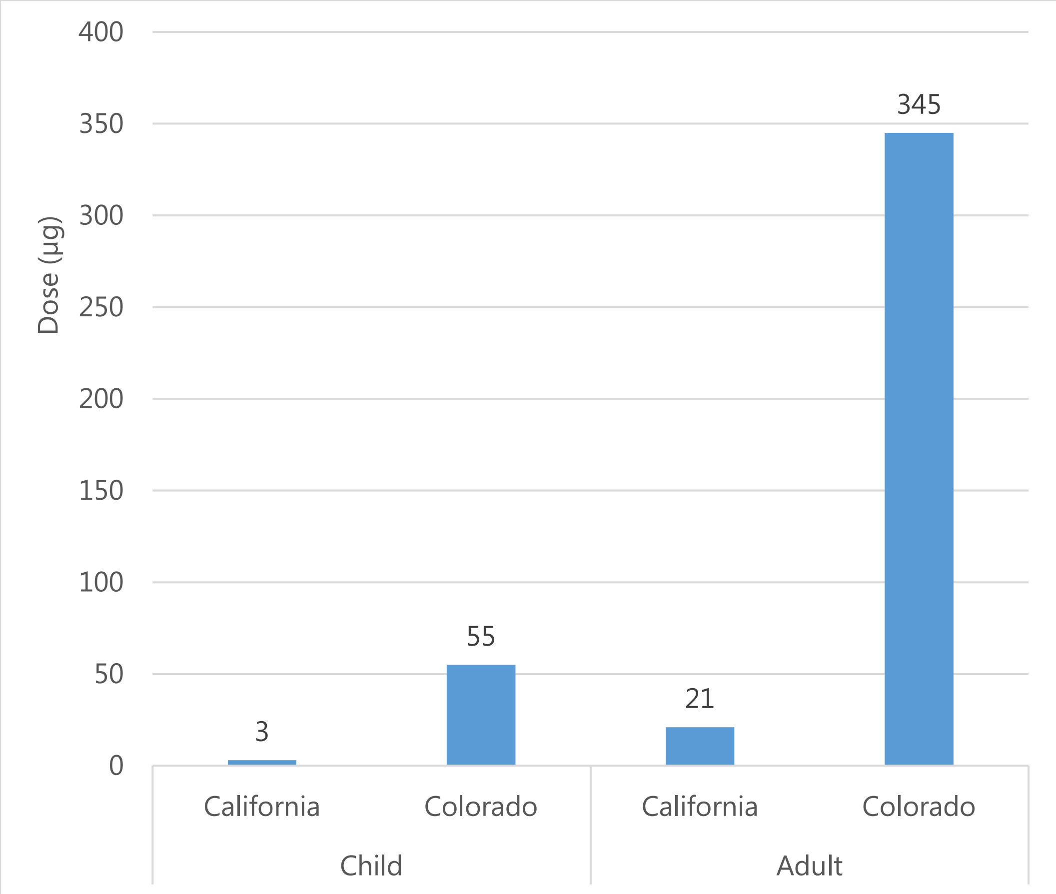

Figure 5: Maximum long-term daily dose of methamphetamine below which adverse events are unlikely to occur (California), or above which an adverse health effect may occur (Colorado), for a 10-kg child and a 70-kg woman.

8.2 Why are there so many different remediation guideline levels?

There are multiple reasons for the considerable variation in remediation guidelines among different agencies.

- Different mathematical models were used to estimate exposure doses: simpler models may take fewer factors into account and involve more simplistic calculations; some may aim to be especially conservative while others provide better exposure estimations but with less of a buffer. Further, the results of modelling can be only as rigorous as the quality of the input data, and each model relies on somewhat different assumptions from the others.
- There is a substantial difference between the California reference dose and the Colorado health-based exposure value (0.3 vs 5–70 µg/kg body weight/day): this in turn directly impacts on the calculated remediation level.
- Unlike the other models, Colorado did not consider the contribution of carpet residues in the exposure calculations. This is because guidelines developed specifically for remediating former meth lab dwellings require that carpets be stripped, so it was assumed that

carpeting in a remediated dwelling would not contain any residues. Australia's Environmental Risk Sciences report [15] did find that including soft surfaces led to a two-fold difference in exposure, but concluded that this difference was "not considered to be sufficiently great" to warrant a separate guideline.

- The ESR report distinguished between former meth labs and non-meth labs, while others did not.
- There are some differences in interpreting the potential for methamphetamine to penetrate materials and re-surface over time.[v]

8.3 Conservative assumptions of exposure dose models

Toxicity assessments

- The toxicity measures derived from California and Colorado's assessments incorporate a large uncertainty factor. This provides a safety 'buffer' to account for factors such as differences in sensitivity among different people, uncertainties from extrapolating animal data to humans, and uncertainties posed by incomplete toxicological information. Both assessments used an uncertainty factor of 300. In other words, the values can be multiplied by 300 to obtain the actual dose that was calculated to either not result in any adverse effect, or result in the first sign of an effect.
- Skin contact is the predominant route of exposure in methamphetamine contaminated dwellings. However the study that led to the lowest level of Colorado's health-based reference value (5 µg/kg body weight/day) involved giving pregnant mice methamphetamine intravenously, which also bypasses oral bioavailability and initial metabolic breakdown, and so is likely to be highly conservative (see footnote x).

Exposure assessments

- Estimates of exposure levels focused on the most sensitive groups such as crawling/mouthing young children, and adult women of childbearing age in whom a fetus could potentially be exposed.
- The models assumed that exposure levels remain constant after remediation, even though simulated smoking experiments have found that even without intervention, levels of smoke residues decrease significantly over just six days [10]. Other factors are likely to contribute to further decreases over time, e.g. through cleaning, coming into contact with clothes and being laundered out, and each exposure event further reducing the remaining residue levels.

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[v] The NZ Ministry of Health [14] disagrees with California's assumption that methamphetamine is volatile (evaporates rapidly) and is not a persistent contaminant. It argues that residues may be absorbed in building materials and later re-surface and evaporate, leading to prolonged exposure and at levels higher than indicated by surface testing alone. There is some evidence for this in the literature [57]. However, ESR considers these factors to be of minimal concern for several reasons. For example, the contribution of airborne methamphetamine to overall exposure is low, and over time young children are likely to reduce their exposure though fewer mouthing behaviours, and reduce their effective dose due to increasing body weight.

- Colorado's model appears to be especially conservative: it assumes that a child is clad in just a nappy, with all its uncovered skin being continuously exposed to contaminated surfaces for 12 hours a day.
- For methodological reasons, ESR's model assumed that methamphetamine was 100% bioavailable through oral ingestion, but in practice bioavailability is thought to be 67% [58]. This means that about one-third of the drug ingested is not actually absorbed.

8.4 Contamination level at which Colorado's health-based reference value is reached

Colorado's health-based reference value of 5–70 µg/kg body weight/day is at least 16-fold higher than California's reference dose (RfD) of 0.3 µg/kg body weight/day. Because the Colorado figure is much less conservative, it could be expected that their clean-up level would be much higher than California's guideline of 1.5 µg/100 cm^2. Yet, their chosen guideline of 0.5 µg/100 cm^2 is 3-fold lower.

This is because Colorado adopted a 'health protective' approach that simply assessed exposure doses at a range of proposed clean-up levels (0.01, 0.1, and 0.5 µg/100 cm^2), and whether any of these levels would result in doses that exceed their health-based reference value. As none of the proposed levels led to an exceedance, the highest level of 0.5 µg/100 cm^2 was selected. They did not assess even higher clean-up levels, or calculate the *maximum* clean-up level at which the health-based reference value would be reached.

However there is expert opinion that such an approach is reasonable [59]. From the Colorado exposure data, it can be calculated that the maximum surface concentration for not exceeding the lowest level of their health-based reference value (5 µg/kg body weight/day) is **13 µg/100 cm^2**.[w] This means that levels exceeding 13 µg/100 cm^2 may – but would be extremely unlikely to, given the 300-fold safety margin – lead to onset of an adverse effect.

As previously noted, the degree of conservatism of the assumptions used in models of exposure can have a large impact on the calculated guideline. This can be illustrated by recalculating Colorado's exposure data using two modified assumptions: a lower oral bioavailability (from 100% to 67%), and lower skin absorption (from 10% to 3%) [60]. For the latter variable, Colorado used 10% as a default value recommended by the US Environmental Protection Agency because no data for skin absorption of methamphetamine were available. However, data from a PhD thesis studying the pharmacokinetics of methamphetamine suggests that the skin absorption could reasonably be assumed to be 3% [60, 61].[x] Using a lower oral bioavailability alone, or lower skin absorption alone, resulted in a maximum level of

[w] An infant is estimated to be exposed to 0.19 µg/kg body weight/day at a surface level of 0.5 µg/100 cm^2. Extrapolation of this relationship, which has been determined to be linear [59], shows that exposure to 5 µg/kg body weight/day will result from a surface level of 13.1 µg/100 cm^2.

[x] California and ESR used a value of 57% based on data from an unpublished draft report (Hui X & Maibach HI (2007) *In vitro* percutaneous absorption of d-methamphetamine hydrochloride through human skin. Draft Report. Department of Dermatology, University of California, San Francisco).

about **15 µg/100 cm^2**; combining both modified variables resulted in further increase of the maximum level to **25 µg/100 cm^2**.

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