A 24-Hour Study to Investigate Chemical Exposures Associated with Clandestine Methamphetamine Laboratories

August 11, 2005

By

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Acknowledgements

This project was sponsored by the United States Department of Justice through a COPS grant awarded to the Colorado Springs Police Department. We'd like to thank Sgt. Terry Curry of the Colorado Springs Police Department for coordinating this exercise and allowing us to participate in this study. In addition, the Colorado Springs Police Department provided site security and logistical support. The Colorado Springs Fire Department provided the house to perform the cook in and also graciously provided emergency response, decontamination, and logistical support. We'd like to thank David Love and associates from the United States Drug Enforcement Agency in San Diego for providing technical expertise for this study.

Introduction

The State of Colorado as well as the nation face an unprecedented epidemic of clandestine methamphetamine drug manufacturing. Seizures of methamphetamine drug laboratories continue to rise putting police and fire first responders at risk for a variety of hazards. The number of seizures in Colorado has risen dramatically from 31 laboratories in 1998 to 455 laboratories in 2001. First responders and susceptible third parties, such as children, are at risk for exposures to the chemical hazards and the fire, explosion, and safety hazards inherent with clandestine manufacture of methamphetamine.

The Centers for Disease Control reported 59 events associated with methamphetamine labs where emergency services personnel were injured during the investigation between 1996 and 1999. The number of injured responders was 155 with most reporting respiratory irritation.[1]

Studies conducted by Dr. Jeffrey Burgess[2,3] at the University of Washington investigated the symptoms reported by emergency responders during illegal methamphetamine laboratory seizures. Responders predominately reported general irritant symptoms, but least one case of phosphine gas exposure was reported. In a questionnaire study of emergency responders, 53.8% reported at least one illness while conducting laboratory seizures with most symptoms appearing to be related to chemical exposure at the laboratory site. The primary symptoms reported were headache and mucous membrane irritation.

Although the predominant symptoms were irritant symptoms, a number of responders were found to have lung function changes as evidenced by an accelerated drop in one second forced expiratory volume (FEV_1) .The majority of symptoms reported by officers occurred during the processing phase of the laboratory seizures which was also the phase in which the most time was spent in the laboratory area. The use of respiratory protection did seem to reduce the incidence of symptoms while investigating these laboratories. There has also been anecdotal evidence of exposure to methamphetamine causing permanent lung damage, but the actual cases have not been reported in the literature.

Martyny et. al. (2003, 2004) has studied chemical and methamphetamine exposures in methamphetamine labs during cooking conditions and as well as the contamination of methamphetamine labs several days after a cook. However, there is no information regarding exposures to these chemicals after a cook during “average living conditions” such as walking through a room, vacuuming, etc. There is also no information on the extent of exposure to a child due to skin or clothing contact with a methamphetamine-contaminated environment. The five goals of this study were to:

- Assess the identities and exposure concentrations of chemicals generated during a methamphetamine cook, in both the direct cook area and remote areas of the house.

- Determine the extent of methamphetamine contamination in terms of distance of spread and amount accumulated after multiple cooks in the same home.

- Measure the persistence of methamphetamine and chemical contaminants within a structure for up to 24 hours after a cook.

- Investigate the ability of normal daily activities such as walking through the house, vacuuming, and moving furniture to re-suspend methamphetamine and other chemical contaminants the day after a methamphetamine cook.

- Determine the actual aerosol size distribution of methamphetamine generated during a cook and from normal daily activities the day after a cook.

Figure 1: The house used for the experiment

Sampling Methods

In order to evaluate potential exposure to airborne methamphetamine and chemical contaminants air samples were collected for methamphetamine, volatile organic hydrocarbons, iodine, hydrochloric acid, and phosphine. Surface samples including wipe samples and vacuum samples were collected for methamphetamine to assess the extent of contamination.

Total airborne methamphetamine was collected using personal sampling pumps calibrated to a flow rate of approximately 2 liters per minute (lpm). Samples were

collected onto an acid treated 37 mm glass fiber filter. Respirable methamphetamine samples were collected using personal sampling pumps calibrated to a flow rate of approximately 2.5 liters per minute with a SKC aluminum cyclone (#225-01-02) supplied with an acid-treated 37 mm glass fiber filter. Aerosol size selective methamphetamine samples were collected on three stages (>2.5 µm, 2.5-1 µm, and < 1 µm) of a Sioutas Personal Cascade Impactor calibrated to 9 lpm with 25 mm acid-treated glass fiber filters. All methamphetamine samples were sent to Data Chem Laboratories for analysis with GC/MS using an in-house method under development for NIOSH.

The samples for volatile organic compounds (VOCs) were collected using a carbotrap thermal desorption tube supplied by Data Chem Laboratories. Thermal desorption tubes consist of multi-layered charcoal sorbent through which a known volume of air is drawn using a flow-calibrated personal sampling pump. These samples were collected at a flow rate of approximately 50 cubic centimeters per minute (cc/min). After sampling, the tubes were packaged in airtight containers and shipped to Data Chem Laboratories for analysis. At Data Chem, the samples were thermally desorbed and analyzed using a GC/MS according to the EPA method T0-17.

Samples were collected for airborne iodine using charcoal tubes (SKC #226-67) combined with a personal sampling pump calibrated to a flow rate of approximately 1.0 lpm. After sampling, these tubes were capped and sent to Data Chem Laboratories where they were analyzed by ion chromatography using NMAM 6005.

The hydrochloric acid samples were collected using a silica gel tube (SKC #226-10-03) and a personal sampling pump calibrated to an approximate flow rate of 200 cc/min. After sampling, the tubes were capped and sent to Data Chem Laboratories for ion chromatography analysis using NMAM 7903.

Phosphine was measured with an electrochemical sensor-using an Industrial Scientific ITX Multi-Gas instruments. These instruments were used only for real-time feedback during this experiment, results were not data logged and are not reported.

Wipe samples for methamphetamine were collected by wiping a 100 cm^2 area with a sterile four inch by four inch (4"x4") gauze wipe. Prior to entering the methamphetamine cook area, the 4x4 wipes were individually placed into sealed plastic centrifuge tubes. After entering the cook area, the gauze was taken out of the tubes and wetted with several milliliters of reagent grade methanol prior to wiping the designated surface. Cross contamination was minimized by using separate pairs of gloves between sample locations. After sampling, the wipes were put back into the centrifuge tubes and sent to Data Chem Laboratories for analysis with GC/MS using an in-house method under development for NIOSH.

Vacuum samples for methamphetamine were obtained by vacuuming a 1 square meter section of carpeting using a Eureka Sanitare Commercial vacuum cleaner. Samples were collected on an Indoor Biotechnologies Mitest Dust collection device that attaches to the hose of the vacuum cleaner. The carpet was vacuumed in two directions and the sample

collector sent to Data Chem Laboratories for analysis with GC/MS using an in-house method under development for NIOSH.

Experimental Design

The experiment was divided into two days. Day 1 of the experiment was dedicated to manufacturing 2 batches (approximately 3 grams for each cook) of methamphetamine using the Red P method. The duration for each cook was approximately 4 hours. Day 2 of the experiment was designed to look at residual chemical levels and methamphetamine contamination 12-24 hours after the cook. Initial "no activity" samples were taken approximately 13 hours after the 2nd cook to determine the concentrations of chemicals prior to "medium" and "heavy" activities during the day. Medium activities, such as walking through the home, sitting on the couch, and opening/closing cabinet doors were performed 16 hours after the 2nd cook. At 18 hours, heavy activities, such as vacuuming, fluffing pillows, and walking or crawling through the home were performed to evaluate a "worst case" scenario of re-suspension of residual methamphetamine. Table 1 summarizes the chemical sampling activities for the experiment. Figure 2 shows a diagram of the house and sampling locations.

Air samples for total methamphetamine, respirable methamphetamine, particle size selective methamphetamine, VOCs, iodine, and hydrochloric acid were collected at two locations in the home during Day 1 of the experiment. The locations included:

1. The Cook Area which was an area in the immediate vicinity of the cooking process.

2. The Remote Area which was an area in an adjacent room approximately 15 feet from the cook area designated as the "den".

On Day 2, the sampling was reduced to a single location inside the kitchen area approximately 4 feet from the cook.

Wipe samples were taken in six different locations throughout the house. Five of the six were wall samples and one location was on the floor in the kitchen approximately 92" from the cook.

Vacuum samples for methamphetamine were collected before the cooks were conducted on Day 1. Areas 1 and 2 for each room were combined to create a composite background sample. Approximately 16 hours after the 2nd cook (Day 2), the carpet areas were again vacuumed to study methamphetamine contamination between the "no activity" and "medium activity" sessions of the experiment. These samples were not composited and are therefore reported as discreet samples.

Airborne methamphetamine was collected using three different sampling apparatus in order to determine the total methamphetamine in the air, respirable fraction of methamphetamine, and the aerosol size distribution of airborne methamphetamine (>2.5 μm, 2.5-1 μm, and < 1 μm). Each type of sample was collected during each cook, 13

hours after the cook (and no activity in the home), 16 hours after the cook during medium activity, and at 18 hours after the cook during heavy activities.

Table I - Summary Chemical Sampling Activities

					Methamphetamine				
		Hydrochloric Acid	Iodine	VOCs	Surface Wipe	Total Vacuum	Air	Respirable	Size Selective
Day 1:	Pre-Cook			x	x	x			
	Cook # 1	x	x	x			x	x	x
	Post Cook # 1				x				
	Cook # 2	x	x	x			x	x	x
	Post Cook # 2				x				
Day 2:	No Activity	x	x	x	x	x	x	x	x
	Medium Activity	x	x	x	x		x	x	x
	Heavy Activity	x	x	x	x		x	x	x

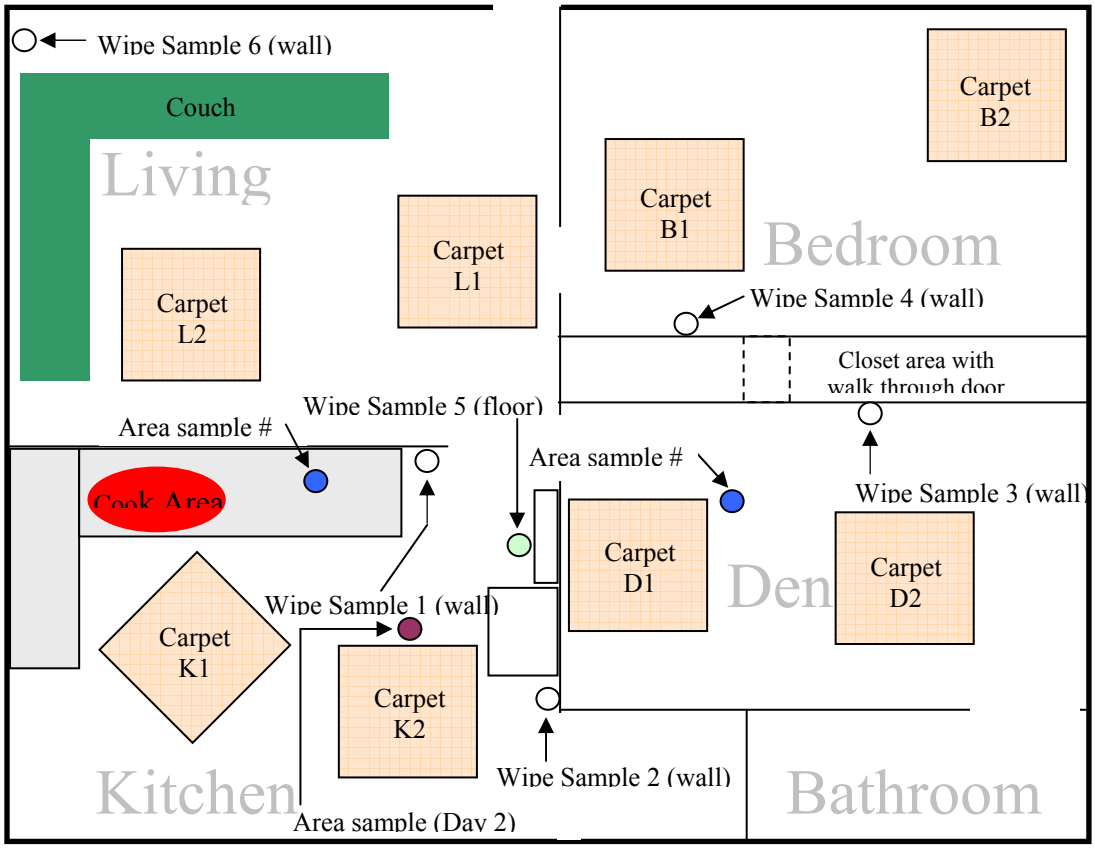

Figure 2: Floor Plan and sample locations

Table II -Health Criteria Reference Concentrations for Sampled Substances

Chemical	CAS#[a]	Occupational Exposure Limits		General Population Minimum Risk Values			Immediate Risk Values
		OSHA PEL[b] (ppm)	ACGIH TLV[c] (ppm)	EPA RfC[d] (ppm)	Cal EPA RfC[e] (ppm)	ATSDR MRL[f] (ppm)	IDLH[g] (ppm)
Ammonia	7664-41-7	50	25	0.1	0.3	0.1	300
Iodine	7553-56-2	0.1 (C)	0.1 (C)				2
Hydrogen Cloride	7647-01-0	5 (C)	2 (C)	0.06	0.006		50
Phosphine	7803-51-2	0.3	0.3	0.0002	0.0006		50
VOCs							
Acetone	67-64-1	1000	500			13	2500
Benzene	71-43-2	1	0.5		0.01		500
Ethylbenzene	100-41-4	100	100	0.2	0.5		800
Trimethylbenzene	25551-13-7		25				
Benzyl chloride	100-44-7	1	1				10
Methylene chloride	75-09-2	25	50		0.1	0.3	2300
2-butanone	78-93-3	200	200	2			3000
Chloroethane	75-00-3	1000	100	0.4	11		3800
Bromomethane	74-96-4	20 (C)	5	0.001	0.001	0.005	2000
Chloromethane	74-87-3		50	0.04		0.05	2000
Ethanol	64-17-5	1000	1000				3300
Ethyl acetate	141-78-6	400	400				2000
Heptane	142-82-5	500	400				750
Hexane	110-54-3	500	50	0.06	2	0.6	1100
Cyclohexane	110-82-7	300	100	2			1300
Isopropyl alcohol	67-63-0	400	200		3		2000
Toluene	108-88-3	200	50	0.1	0.08	0.08	500
Xylene	1330-20-7	100	100	0.02	0.2	0.1	900

Notes: (ppm=parts per million)

a) Chemical Abstracts Number – unique to every chemical
b) Permissible Exposure Limits as established by the U.S. Occupational Safety and Health Administration, a legally enforceable exposure concentration in occupational environments. All values are 8-hour average concentrations unless designated with a (C) indicating a ceiling concentration never to be exceeded.
c) Threshold Limit Values as established by the American Conference of Governmental Industrial Hygienists. These are "best practice" guidelines for occupational environments. All values are 8-hour average concentrations unless designated with a (C) indicating a ceiling concentration never to be exceeded.
d) Reference inhalation concentration as established by the U.S. Environmental Protection Agency. This value is based on a chemical risk assessment to establish a "minimal risk" long-term exposure concentration for members of the general public including sensitive subpopulations such as children and the elderly.
e) Reference inhalation concentration as established by the California Environmental Protection agency. Definition the same as d above.
f) Minimum Risk Level as established by the U.S. Agency for Toxic Substances and Disease Registry. Definition the same as d and e above.
g) Immediately Dangerous to Life or Health concentration, chemical concentrations at or above this value can cause immediate health consequences or risk of fire or explosion.

Results

Table III summarizes the concentrations of hydrochloric acid, iodine, and 18 identified volatile organic compounds detected during the experiment.

Table III - Summary of Chemical Concentrations During the Experiment

	Day 1					Day 2		
						13 Hours Post Cook # 2	16 Hours Post Cook # 2	18 Hours Post Cook # 2
Chemical	**Pre-Cook**	**Cook #1 Cook Area**	**Cook #1 Remote Area**	**Cook #2 Cook Area**	**Cook #2 Remote Area**	**No Activity**	**Medium Activity**	**Heavy Activity**
Hydrochloric Acid (ppm[a])		0.27	0.029	0.42	0.16	ND	0.041	0.065
Iodine (ppm[a])		0.12	0.0051	0.01	0.0046	0.005	0.0049	0.002
VOCs (ppb[b])								
acetone	9.9	ND	ND	ND	12	130	500	940
benzene	ND	1.7	0.64	2.6	0.47	ND	ND	ND
ethylbenzene	ND	0.75	0.42	ND	ND	ND	ND	ND
1,2,4 trimethylbenzene	1.7	0.62	0.31	1.6	ND	ND	ND	ND
benzyl chloride	ND	1.3	ND	19	ND	ND	ND	0.67
methylenechloride	ND	ND	0.86	0.81	0.48	ND	500	3.9
2-butanone	ND	ND	ND	0.86	ND	ND	ND	2.3
chloroethane	ND	1.1	ND	16	15	ND	ND	ND
chloromethane	ND	1.6	ND	1.5	ND	ND	ND	ND
ethanol	5.7	9.8	12	21	ND	ND	16	4
Ethyl acetate	ND	ND	ND	0.96	ND	ND	ND	ND
heptane	ND	120	39	280	0.91	36	32	53
hexane	ND	41	32	150	ND	16	26	61
cyclohexane	ND	140	43	280	23	76	87	100
Isopropyl alcohol	ND	ND	13	260	ND	ND	32	4.9
toluene	ND	2.1	1.2	6	ND	0.98	ND	ND
4-ethyl toluene	1.7	ND	ND	1.3	ND	ND	ND	ND
m,p-xylene	ND	ND	1.1	ND	ND	ND	ND	ND

[a] ppm = parts per million

[b] ppb = parts per billion

ND= Not Detected

Blank spaces indicate that a sample was not taken

Hydrochloric Acid

During the cooks, hydrochloric acid concentrations were the highest in the cook area with values of 0.27 ppm and 0.42 ppm for the first and second cooks respectively. The remote area, located 15 feet away from the cook area, had concentrations of hydrochloric acid of 0.029 ppm and 0.16 ppm for the two cooks. All of these levels are well below OSHA's ceiling concentration of 5 ppm. However, the samples were collected over a four-hour time period and do not reflect the peak exposures likely to be seen during the salting out phase of the cook. Prior Red P cooks conducted by the Drug Enforcement Agency and

National Jewish have demonstrated that hydrochloric acid levels can be as high as 150 ppm during this salting out phase.

Hydrochloric acid results from Day 2 of this project indicate that normal household activities can re-aerosolize hydrochloric acid at least as long as 18 hours after the cook. Hydrochloric acid concentrations were 0.041 ppm and 0.065 ppm during medium and heavy activities on the day following the cook. While these concentrations are well below all established occupational exposure limits, they are well above the chronic inhalation reference concentration (RfC) of 0.006 ppm established by the California Environmental Protection Agency. Based on this information, persons living in the methamphetamine lab and chronically exposed to similar hydrochloric acid concentrations may be at higher risk of adverse upper respiratory health effects.

Iodine

During cook #1, the average iodine concentration in the cook area was 0.12 ppm which exceeds the ceiling limit for occupational exposure of 0.1 ppm. Since, the majority of the iodine is produced during the actual cooking phase, it is very likely that peak concentrations were orders of magnitude higher than 0.1 ppm. Levels of iodine as low as 0.3 ppm have been reported to cause severe mucous membrane irritation. Iodine levels during cook #2 were much lower with an average concentration of 0.029 ppm. Concentrations in the remote area were 0.0051 ppm and 0.0046 ppm for cooks #1 and 2 respectively. Iodine concentrations were detectable even 18 hours after the last cook at concentrations similar to those seen in the remote area during the cooks ranging from 0.002 ppm to 0.005 ppm.

Volatile Organic Compounds

Analysis for VOCs yielded only 18 positively identifiable chemical compounds during the two days of sampling. Average concentrations of all identified VOCs were below 1 ppm, even during the actual cooks and extraction process. Concentrations of heptane, hexane, and cyclohexane were consistently higher than other identified VOCs with maximum average concentrations ranging from 32 ppb to 280 ppb during the two cooks. This result is consistent with the measurements in Day 2, where concentrations of these chemicals continue to be higher than other identified VOCs. All three of these chemicals are components of the extraction solvent used during the manufacture of methamphetamine. No VOCs were identified at concentrations close to or exceeding any occupational exposure limits or general population minimum risk values.

Airborne Methamphetamine

Table IV summarizes the results of the airborne methamphetamine sampling. During the cooks, airborne total methamphetamine concentrations were 520 $\mu g/m^3$ and 760 $\mu g/m^3$ in the cook areas. In the remote sampling area, concentrations were 99 $\mu g/m^3$ and 510 $\mu g/m^3$ for cooks 1 and 2 respectively. Respirable samples showed methamphetamine concentrations at very similar levels to the total airborne samples. This finding indicates that virtually all of the methamphetamine aerosol is of respirable size capable of deep penetration into the lungs to the gas exchange regions where rapid bloodstream absorption is likely. Aerosol size selective sampling results underscore the above finding

indicating that as much as 90% of the methamphetamine mass is collected on the final filter of the cascade impactor during the cooking process. Analysis of this data indicates the mass median aerodynamic diameter of the methamphetamine aerosol is less than 0.1 µm. Due to the smoke generated during the methamphetamine manufacturing process, it has been previously assumed that much of the airborne concentration was in an aerosol or particle state. Data from this experiment may indicate that the majority of airborne methamphetamine is actually present in a vapor state.

Table IV - Airborne Methamphetamine

	Day 1				Day 2		
Airborne Methamphetamine (ug/m^3)	**Cook # 1 Kitchen**	**Cook # 1 Den**	**Cook # 2 Kitchen**	**Cook #2 Den**	**No Activity**	**Medium Activity**	**Heavy Activity**
Total Airborne Methamphetamine	520	99	760	510	70	170	210
Total Airborne Methamphetamine (high flow)					117	106.5	100.6
Respirable Methamphetamine	720	97	780	460	76	150	180
Aerosol Size Selective Methamphetamine							
Particles >2.5 µm	48	7.2	19	85	0.66	1.1	1.9
Particles from 1.0 - 2.5 µm	56	6.5	26	18	0.77	1.3	1.4
Particles < 1.0 µm	230	99	370	250	79	110	99

Data from Day 2 of this experiment show that airborne methamphetamine is detectable at significant concentrations more than 13 hours after a methamphetamine cook, even with no activity in the structure. Both medium and heavy activity appear to increase the airborne concentrations indicating probable re-suspension of methamphetamine from contaminated surfaces. Respirable and aerosol size selective sampling show results similar to those seen during the cooking process – that the majority of airborne methamphetamine is of respirable size and likely present as a vapor rather than a particulate aerosol.

Vacuum Samples for Methamphetamine

Table V summarizes the vacuum samples collected prior to the cook, during the cook, and on the day after the cook. Based on these results, it appears that either the carpet had previously been contaminated with methamphetamine or that there were interferences in the sample due to the large mass of carpet fibers and dust collected during collection of the first vacuum sampling. Post-cook samples show predictable results with the highest levels of methamphetamine contamination found in the cook area (kitchen) and living room where there was a lot of foot traffic during the cooking process. Samples from the den and bedroom indicate that methamphetamine migrates easily through a structure contaminating all surfaces. Significant carpet contamination also has important implications for children residing in a methamphetamine house due to crawling and frequent hand-to-mouth behavior.

Surface Wipe Samples for Methamphetamine

Table VI summarizes the wipe sample data for methamphetamine. Surface wipe results ranged from 1.5 µg/100cm^2 of methamphetamine to levels as high as 230 µg/100cm^2 on the toy truck approximately 24" above the cook area. In general, the concentration of methamphetamine on surfaces increased over time. The pre-cook wipe samples indicate that methamphetamine had been used in the home prior to the experiment. These low

levels suggest that methamphetamine was used (likely smoked) in the home rather than being manufactured in the home. Samples closer to the cook area had higher contamination levels and samples father away from the cook had less contamination. These results also show very little if any reduction in methamphetamine surface contamination levels as long as 18 hours after the cook.

Table V - Carpet Vacuum Sample Results

Vacuum Samples (ug/m^2)	Pre-Cook	13 Hours Post Cook	
Kitchen	5	K1	270
		K2	140
Den	5.5	D1	94
		D2	54
Living Room	2.65	L1	120
		L2	110
Bed Room	4.35	B1	82
		B2	79

Table VI - Surface Wipe Summary Results

Wipe Samples (ug/100cm^2)	Pre-Cook	Post Cook #1	Post Cook #2	13 Hours Post Cook # 2	16 Hours Post Cook # 2	18 Hours Post Cook # 2
Wipe Area 1	13	31	45	46	68	46
Wipe Area 2	23	39	45	41	59	44
Wipe Area 3	18	45	29	31	33	42
Wipe Area 4	14	29	19	32	36	35
Wipe Area 5	1.5	6.9	8.6	6.1	6.7	10
Wipe Area 6	5.7	29	30	36	23	37
Toy truck above cook area						230

Blank spaces indicate that a sample was not taken

Figure 3: Wipe sample location 4

Personal Wipe Samples

Table VII summarizes the wipes taken on personnel exiting the methamphetamine lab.

Table VII - Personal Wipe Sample Summary

Person	Location	Activity	Methamphetamine (µg/100cm^2)
7	Arm	Low	0.45
	Foot	Low	0.78
	Neck	Low	0.19
3	Arm	Low	0.075
	Foot	Low	1.7
	Neck	Low	0.69
3	Arm	Medium	0.32
	Foot	Medium	2.3
	Neck	Medium	0.62
4	Arm	Medium	0.36
	Foot	Medium	11.7
	Neck	Medium	0.3
5	Seat	Medium	1.3
	Hands	Medium	56
6*	Knee	Medium	0.54
	Neck	Medium	1
	Hands	Medium	29
1	Arm	High	0.59
	Foot	High	44
	Neck	High	0.61
2	Arm	High	0.7
	Foot	High	15
	Neck	High	0.46

* Firefighter crawled on floor to simulate baby crawling on floor.

Figure 4: A firefighter crawls on the floor to simulate an infant crawling.

The heaviest contamination found on personnel coming out of the methamphetamine lab was found on the boots. This is likely due to the boots having more contact time with various surfaces in the methamphetamine lab. It may be of significance to note the high methamphetamine concentration found on the hands of person #6 who crawled on the floor to simulate an infant. Because infants have a tendency to place their hands in the mouth, they may be more subject to exposing themselves to higher levels of methamphetamine.

Personal Wipe Samples: Effectiveness of Decontamination

Table VIII summarized the samples collected to compare the effectiveness of wet and dry decontamination procedures. As we only have two samples for each of the decontamination procedures, it is difficult to draw any firm conclusions. However, it can be said based on these results, both methods can leave some residual contamination. Additional data on this topic is currently being conducted as part of a larger study.

Table VIII - Comparison of wet vs. dry decontamination

Person	Location	Pre Decon	Post Decon	Methamphetamine ($\mu g/100cm^2$)	Wet Decon	Dry Decon	Protective Clothing
A	Right Arm	x		4.3		x	Saranex
	Right Boot	x		5.7		x	
	Back of Neck	x		8.3		x	
	Right Arm		x	ND		x	
	Right Boot		x	ND		x	
	Back of Neck		x	ND		x	
B	Right Arm	x		ND		x	Tyvek
	Right Boot	x		12		x	
	Back of Neck	x		230		x	
	Right Arm		x	9.1		x	
	Right Boot		x	ND		x	
	Back of Neck		x	ND		x	
C	Right Arm	x		7.4	x		Saranex
	Right Boot	x		26	x		
	Back of Neck	x			x		
	Right Arm		x	ND	x		
	Right Boot		x	ND	x		
	Back of Neck		x	ND	x		
D	Right Arm	x		14	x		Tyvek
	Right Boot	x		23	x		
	Back of Neck	x		5.8	x		
	Right Arm		x	0.11	x		
	Right Boot		x	ND	x		
	Back of Neck		x	ND	x		

Study Conclusions

This study was designed to determine the primary chemical exposures associated with clandestine methamphetamine laboratories and study the migration and persistence of the chemicals over a 24-hour period. In addition, this study looked at various activities, such as walking and vacuuming in the methamphetamine lab to determine exposures that may result from re-suspension of chemicals from contaminated surfaces. Based on our findings, we make the following conclusions:

- Detectable airborne concentrations of hydrochloric acid, iodine, and methamphetamine will remain within a structure for at least 24 hours.

- Normal household activities, such as walking and vacuuming can re-suspend hydrochloric acid, iodine, and methamphetamine from contaminated surfaces.

- Airborne methamphetamine exposures on the day after a methamphetamine cook are similar to those seen in remote areas of a house during a cook.

- The majority of airborne methamphetamine is present as very small particles (< 1 μm) or as a vapor. This finding indicates methamphetamine during a methamphetamine cook or up to 24 hours after a methamphetamine cook penetrates deep into the lungs to the gas exchange region where it is rapidly absorbed into the bloodstream.

Study Limitations

Each methamphetamine lab is unique with regards to how the cook is performed, the procedures to cook the drug, the chemicals used, and the structure used to cook methamphetamine. Even using the same chemist, chemicals, and procedures can produce widely varied yields of methamphetamine and contamination. Therefore, the results in this study are a snapshot of potential contamination found in methamphetamine labs. Readers should understand that exposure concentrations under actual conditions may be lower but they may also be much higher.

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