Chemical Exposures Associated with Clandestine Methamphetamine Laboratories Using the Hypophosphorous and Phosphorous Flake Method of Production

September 23, 2005

By

National Jewish Medical and Research Center
Division of Environmental and Occupational Health Sciences
1400 Jackson Street
Denver, Colorado 80206
(303) 398-1983
http://www.nationaljewish.org/

John W. Martyny, Ph.D., CIH - Associate Professor, National Jewish Medical and Research Center

Michael Van Dyke, CIH, CSP
Industrial Hygienist, National Jewish Medical and Research Center

Charles S. McCammon, Jr., Ph.D., CIH
Senior Industrial Hygienist, Tri-County Health Department

Nicola Erb, MA
Epidemiologist, National Jewish Medical and Research Center

Shawn L. Arbuckle
Industrial Hygiene Program Coordinator, National Jewish Medical and Research Center

Acknowledgements:

This project was made possible by the Southwest Laboratory of the Drug Enforcement Administration of the United States Department of Justice, located in Dallas, Texas. The DEA Law Enforcement group was critical in locating the structures, supplies, managing the emergency response groups, and assisting our research team in conducting this research. We also acknowledge the role of the Drug Enforcement Administration Forensic Chemists, specifically David Love, Tamara Dallabetta, Angela Wacker and Scott Wischenewski who researched and conducted the cooks. The local city and county authorities in Corsicana, Texas were instrumental in providing security and emergency services at the site. Many of the costs of the sampling effort were covered by a Community Oriented Policing Services (COPS) grant. The authors also acknowledge the continuing efforts of Sergeant Jim Gerhardt of the Rocky Mountain HIDTA for his project coordination, topic expertise and video support. Finally, we would like to thank Industrial Scientific Corporation for providing instrumentation for this cook and personnel on scene.

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.

Unfortunately, very little is known regarding the specific exposure hazards faced by first responders and bystanders associated with illegal methamphetamine manufacturing and lab seizure. As a result there is very little information on which to establish appropriate medical treatment as healthcare providers are forced to provide generic, often expensive, and probably to some extent unnecessary medical testing.

The use of personal protective equipment (PPE) by emergency services and law enforcement personnel also vary widely by jurisdiction due to the lack of information regarding chemical exposures at the sites and the necessity for protection. Some jurisdictions use self-contained breathing apparatus and chemical-protective suits while other neighboring jurisdictions use no respiratory protection or chemical-protective suits at all. Other agencies switch from self-contained breathing apparatus to air-purifying respirators after the initial assessment while other agencies remain in the highest levels of protection. These variations are due to a lack of information from scientifically-based studies, relating to exposure risks while conducting these operations.

Even though many agencies use some form of PPE, there are increasing reports of emergency service and law enforcement personnel being injured while conducting investigations at clandestine methamphetamine laboratories. 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. Jefferey Burgess(2,3) while at the University of Washington investigated 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 an accelerated drop in one second forced expiratory volume (FEV_1) that may have been related to work in drug laboratories. The majority of symptoms reported by officers occurred during the “processing” phase of the laboratory seizures. This is likely attributed to the phase of the investigation 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 chemicals present in methamphetamine laboratories causing permanent lung damage but the actual cases have not been reported in the literature.

This increase in illegal laboratory seizures and reported health effects has resulted in health concerns by the emergency services and law enforcement personnel responding to these incidents. Typical concerns expressed by first responders regarding exposures at clandestine methamphetamine laboratory seizures include:

- Was I exposed to something that can harm me?
- Could my exposures cause me health concerns?
- What personal protective equipment should I have been wearing during the lab seizure?
- When was it safe for me to remove my personal protective equipment?

Although the chemicals used in the production of methamphetamine are well known, first responders do not know which of these chemicals by themselves or in combination may be harmful and what routes of exposure present the most severe risks. Industrial hygienists commonly approach such problems by quantifying the actual exposures using air sampling, modeling, and in some cases teamed with occupational environmental medical specialists using biological markers (chemical traces in urine or blood, for example) to determine what the exposure has been. Major exposure assessment issues include individual chemical characteristics as well as potentially complex interactions of chemicals that might result in unusual and potentially very toxic mixtures.

This project was designed to determine the potential chemical exposures to law enforcement and emergency services personnel responding to clandestine methamphetamine laboratory seizures that involve the use of the red phosphorous substitutes; specifically hypophosphorous acid and phosphorous flakes. The results of the project will be utilized to inform decisions regarding PPE, containment, and medical treatment of individuals involved with these responses.

Hypophosphorous Acid and Phosphorous Flake Manufacturing Process

The use of hypophosphorous acid (H_3PO_2) instead of red phosphorous to reduce ephedrine in the manufacture of methamphetamine has reportedly been used internationally since the mid 1990s. This method has been referred to as the “Hypo” method. The National Drug Intelligence Center reports that in the late 1990s a Colorado methamphetamine manufacturer obtained a recipe from Australia, where the methodology was prevalent. The technique was passed to other manufacturers and has been documented in at least California, Nevada, Mississippi, Oklahoma, Missouri and Kansas. While the hypo method is not the primary method of methamphetamine production in Colorado or in other states, the use of the method is likely underreported since chemical identification of acids found at a cook site is usually not performed. Intelligence sources report that illicit demand for hypophosphorous acid has risen due to its use in methamphetamine-manufacturing. The Drug Enforcement Administration actively monitors sales and distribution of this acid.

Another similar method of methamphetamine production using solid phosphorous flakes has also been on the rise, known as the "phosphorous flake" method. This method has been proven in a laboratory setting by Forensic Chemist David Love of the Drug Enforcement Administration and reported at the 2004 Clandestine Laboratory Investigating Chemists International Conference. In this method, water is added to the solid phosphorous flakes to produce hypophosphorous acid. This method is of particular concern due to the ease of accessibility of the phosphorous flakes from agricultural fertilizers.

The advantages to both of these methods for the manufacturer are the ease of production due to the elimination of the solid form of red phosphorous. In more traditional cooking methods, red phosphorous is obtained by the tedious removal of matchbook striker plates. Use of a liquid source of phosphorous rather than a solid also eliminates one of the filtering steps which can be time consuming and lead to loss of product. Additionally, there is no need for determining the adequate amounts of water to add to the solution and the general amount of waste is decreased.

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, phosphoric acid, and phosphine. Air samples were collected in two different areas, the "Cook Area" which was the area in the immediate vicinity of the cooking process and a "Remote Area" which was an area in an adjacent room. A number of samples were also taken in the breathing zone of the DEA Chemists to determine personal exposures during the cook and are designated as "personal samples". Surface wipe samples were collected for methamphetamine to assess the extent of contamination on household surfaces and the effectiveness of decontamination procedures for personnel exiting the cooking area.

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. 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 Summa® canisters supplied by Data Chem Laboratories. These canisters are stainless steel evacuated cylinders that can be used to obtain a fixed volume of air over a very short sampling period (< 1 minute) in the immediate vicinity of the canister. The canister was taken into the clandestine lab area and the valve opened, allowing the tank to fill with the air present within the suspected laboratory. After the tank had filled, the valve was shut and the canister sent to Data Chem Laboratories for analysis with GC/MS by the United States Environmental Protection Agency (EPA) Method T0-15.

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 and phosphoric 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 and hydrochloric acid were measured with an electrochemical sensor-using an Industrial Scientific ITX Multi-Gas instruments. These monitors provide real-time concentrations and data logging that can be used to determine chemical concentrations during the cook at specific time intervals.

Wipe samples for methamphetamine were collected by wiping a 100 cm^2 area with a sterile four inch by four inch (4”x 4”) 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. Similar methamphetamine surface samples were taken prior to and after decontamination process on the chemical protective suits and equipment of the DEA Chemists. 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.

Descriptions of the Test Cooks

Cook #1 was conducted in a dilapidated home scheduled for demolition due to its condition. The dimensions of the structure were approximately 40’ x 25’ and divided into four separate rooms, including the bathroom. The cook was set up in the bathroom area (12’ x 12’) with a closed window. Connecting rooms were blocked off with plastic sheeting to contain the cook and protect assisting personnel and the neighborhood residents. This cook used hypophosphorous acid in the pseudoephedrine/ephedrine reduction method and was conducted by Forensic Chemists David Love and Scott Wischenewski on a plywood sheet placed on the bathtub. The cook was initiated at 10:10 am and was concluded at 2:30 pm, spanning a time period of 4 hours and 20 minutes.

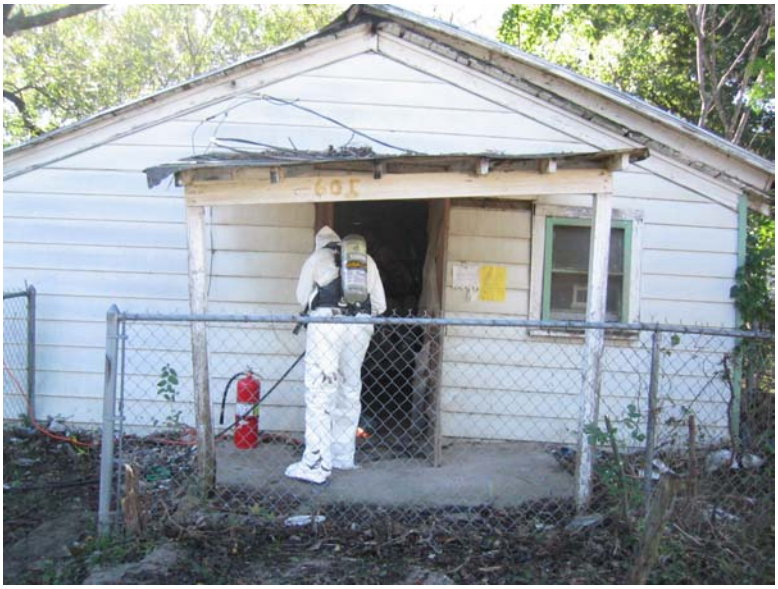

Figure 1. House used for Cook #1.

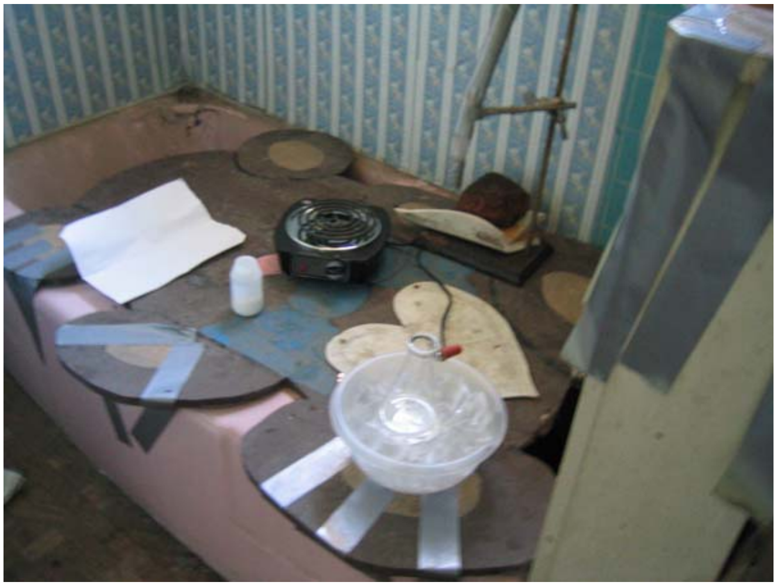

Figure 2. Cook setup in the bathroom of the house used for Cook #1

Cook #2 was conducted across the street from Cook #1 in another dilapidated structure also scheduled for demolition. The ceiling in this structure was lower than normal, at about 6’ 5” in height. The structure dimensions were 20’ x 25’ and consisted of one main living area, a kitchen area divided off only by a counter, a bedroom and bathroom. Furniture, clothing and debris littered the bedroom area and miscellaneous furniture was randomly located throughout the structure. The cook site was set in the rear of the main living area, situated in approximately the center of the overall structure. Cook #2 was performed using phosphorous flakes in the pseudoephedrine/ephedrine reduction method and was conducted by DEA Forensic Chemists Tamara Dallabetta and Angela Wacker on a kitchen table left in the structure. Cook #2 was initiated at 9:25 am and concluded at 1:40 pm spanning four hours and 15 minutes.

Figure 3. House used for Cook #2.

Figure 4. Cook location in the living room of the house used for Cook #2.

Table I – Health criteria Reference Concentration 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 Chloride	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
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
Methyl Cyclohexane	108-87-2	500					1200
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.

Study Results

Phosphine

The phosphine levels were determined using the ITX Multi-Gas Monitors. Phosphine was detected at both of the cooks, although much higher levels were obtained from Cook #1. Table I shows the phosphine levels during each cook.:

Table II – Phosphine Sampling Results

	Cook #1 (ppm)	Cook #2 (ppm)
Minimum	ND	ND
Maximum	13	0.6
STEL Max	7	0.1
TWA	0.9	0.0

The current ACGIH TLV for phosphine is 0.3 ppm with a 1 ppm STEL. The current NIOSH IDLH for phosphine is 50 ppm. The levels measured at Cook #1 were above the current TLV and the STEL for phosphine while the levels measured at Cook #2 were below the current standards. In neither case were the measured levels of phosphine approaching the IDLH values. The highest phosphine levels were observed during the salting-out phase and not during the cooking phase. In fact, the phosphine levels appeared to rise and fall at the same times as the hydrogen chlorine levels. It would be expected that phosphine levels would be higher during the cooking phase than the salting-out phase. There is some concern regarding the cross-reactivity of the phosphine and hydrogen chloride sensors in the monitoring equipment that was used. This cross-reactivity may result in erroneously high phosphine readings in the presence of high concentrations of hydrogen chloride. However, at this time we do not have enough data to indicate that these phosphine concentrations were erroneously high.

Iodine

Airborne iodine levels were measured during both cooks. The first samples were taken during in the initial reaction process in Cook #1 for a time period of 161 - 211 minutes at the immediate cook area, remote area, and personal sampling locations. A second set of measurements were taken during the final step of the process referred to as acidification or "salting out". During this phase, hydrogen chloride gas was bubbled through the liquid to produce methamphetamine HCl solid crystals. These samples were taken during time periods ranging from 46-56 minutes.

In Cook #2, samples were collected during the initial reaction process for a time period of 154-160 minutes. A second set of samples was collected during the acidification process for a time period of 64-65 minutes.

Table III – Iodine Sampling Results

Location	Cook #1 Cooking Phase (ppm)	Cook #1 Salting Out (ppm)	Cook #2 Cooking Phase (ppm)	Cook #2 Salting Out (ppm)
Cook Area	0.005	0.004	ND	ND
Remote Area	0.001	NA	ND	ND
Personal Sample	0.004	0.003	NA	NA

ND = None Detected   NA = Not Available

The current ACGIH TLV for iodine is a ceiling level of 0.1 ppm. All of the levels observed were well below the current standard. Slightly higher levels were measured in Cook #1 as compared to Cook #2.

Hydrochloric Acid

Hydrogen chloride levels were measured during both cooks. The first samples were taken during the initial reaction process in Cook #1 for a time period of approximately 200-212 minutes. The second set of samples were taken during the "salting out" phase for a time period of 46-56 minutes.

In Cook #2, samples were taken during the initial reaction process at the cook site and in the breathing zone of the chemist for a time period of 154-160 minutes. A second set of samples was taken during the acidification process for a time period of 64-65 minutes. The levels of hydrogen chloride were as follows:

Table IV – Hydrogen Chloride Sampling Results

Location	Cook #1 Cooking Phase (ppm)	Cook #1 Salting Out (ppm)	Cook #2 Cooking Phase (ppm)	Cook #2 Salting Out (ppm)
Cook Area	0.13	2.60	0.13	3.1
Remote Area	0.02	0.26	NA	NA
Personal Sample	0.08	0.61	0.21	4.5

NA = Not Available

Real-time Drager tube sampling was also conducted for HCl during the salting out period in the area of Cook #1. Samples were taken in the immediate location of the cook and at the exit doorway. The hydrogen chloride levels found in the cook area ranged from 4 – 12 ppm and approximately 2 ppm at the exit doorway.

Hydrogen chloride levels were also determined using real-time data from the ITX Multi-Gas Monitors. Hydrogen chloride was detected at both cook locations, although much higher levels were obtained during Cook #1. The levels observed were as follows:

Table V – Hydrogen Chloride Sampling Results – Real-Time Data

	Cook #1 (ppm)	Cook #2 (ppm)
Minimum	ND	ND
Maximum	400	90
STEL Max	242	11.2
TWA	23	0.4

The maximum levels for hydrogen chloride were only detected for a short period of time and should not be taken as a long-term concentration. It is interesting to note that the hydrogen chloride levels at Cook #2 were lower than those taken at Cook #1 while the exposures documented by the sampling pumps were higher at Cook #2. This is likely due to the position of the samplers and the fact that Cook #1 was below a window which may have ventilated Cook #1 slightly more that Cook #2. The biggest difference was the personal sample which was on the chemist, who in Cook #1 was standing in a position where the window could have significantly reduced the exposure.

The current ACGIH TLV for hydrogen chloride is a ceiling value of 2 ppm. These data indicate that in both cooks, the environment of the cook was frequently above the TLV at both sites. In addition, especially at Cook #1, the hydrogen chloride levels may have reached levels that were above the NIOSH IDLH of 50 ppm. Hydrogen chloride levels continue to be some of the higher exposures at these sites.

Phosphoric Acid

Although samples for phosphoric acid were taken in conjunction with the hydrogen chloride samples, no detectable phosphoric acid was detected. The minimum detection level for phosphoric acid was 0.6 µg/sample.

Volatile Organic Hydrocarbons

A sample for volatile organic hydrocarbons (VOC's) taken at Cook #2 during the extraction phase showed a few hydrocarbons to be increased over the outdoor air levels. The concentrations observed were as follows:

Table VI – VOC Sampling Results

Chemical	Concentration (ppb)
3,3 – dimethyl-pentane	1,400
C7 Hydrocarbon A	11,000
C7 Hydrocarbon B	6,300
C7 Hydrocarbon C	4,100
Heptane	7,500
Methyl Cyclohexane	890

These hydrocarbons are likely associated with the Coleman lantern fuel that was used to extract the methamphetamine. None of the levels observed approach the ACGIH TLV levels. These results are similar to the results obtained in our other studies.

Airborne Methamphetamine Results

Airborne methamphetamine samples were collected during both cooks. In Cook #1 pumps were placed at the cook site and two others placed in areas away from the cook area. The pumps were in operation for 204-210 minutes for the initial reaction phases (pre-salting out) and during the salting out phase for 55 minutes. The airborne methamphetamine results for Cook #1 were as follows:

Table VII – Airborne Methamphetamine Results from Cook #1

Location	Pre-Salting Phase (µg/m^3)	Salting Phase (µg/m^3)
Cook Area	<0.12	3800
Distant Room Area #1	<0.11	960
Distant Room Area #2	N/A	4000

In Cook #2 the samples were taken at the cook site and across the room during the Pre-salting phase. The samples were collected for 121-125 minutes. During the salting-out phase only one pump was used at the cook site and samples were collected for 66 minutes. The results obtained during Cook #2 were as follows:

Table VIII – Airborne Methamphetamine Results from Cook #2

Location	Pre-Salting Phase (µg /m^3)	Salting Phase (µg /m^3)
Cook Area	<0.19	680
Distant Room Area	<0.17	N/A

These levels again indicate that a significant amount of methamphetamine is liberated during the salting-out phase of methamphetamine production. These levels are similar to the levels observed in most red phosphorous cooks.

Methamphetamine Wipe Results

Wipe samples were taken at several locations within the buildings. The initial samples were taken to assure that there had been no pre-contamination with methamphetamine at the sites. None of the background samples had detectable levels of methamphetamine present. The results of the methamphetamine wipe samples and the areas they were taken from were as follows:

Table IX – Methamphetamine Surface Results

Cook	Sample #	Description and Location	Post Cook Results (µg/100cm^2)
#1	1A	Painted Wall above the Cook: 5'4" from the cook and 5' 4" off the floor	14.0
	1B	Window Above the Cook: 4' 0" from the cook and 6' 0" from the floor	23.0
	1C	Mirror Across from the Cook: 7' 0" from the cook 3' 8" from the floor	7.5
	1D	Outside Door of the Cook: 7' 2" from the cook and 5' 3" feet from the floor	4.6
#2	2A	Glass Surface: 15" from the cook and 4" off the floor	0.067
	2B	Glass Surface: 2" from the cook and 4" off the floor	1.2
	2C	Glass Surface: 10' from the cook and 3'6" off the floor	0.078
	2D	Painted Surface: 6' from the cook and 6'2" off the floor	0.18

These data suggest that a single cook within a structure will result in significant methamphetamine contamination on surfaces within the structure. The reason for the lower levels of contamination at Cook #2 is not known at this time.

Wipe samples were also taken on the suits of the cooks both before and after decontamination. Prior to decontamination, samples were taken from the front and from the back of the protective outer suit. After decontamination, samples were taken from the inside of the mask and from the bare arm of the cook. The results of this sampling were as follows:

Table X – Methamphetamine Decontamination Samples

	Location	Pre or Post Decon	Methamphetamine (µg/wipe)
Cook #1A	Front	Pre	6.4
	Back	Pre	4.6
	Mask	Post	28
	Arm	Post	ND
Cook #1B	Front	Pre	9.4
	Back	Pre	1.6
	Mask	Post	18
	Arm	Post	ND
Cook #2A	Front	Pre	3.7
	Back	Pre	1.1
	Mask	Post	6.0
	Arm	Post	ND
Cook #2B	Front	Pre	1.8
	Back	Pre	0.16
	Mask	Post	1.2
	Arm	Post	ND

Samples were taken on a toy that was present in the area of each cook as well as a baby suit of clothes that was hanging in the vicinity of each of the cooks. The results of these samples were as follows:

Table XI – Bulk Samples for Methamphetamine

Item	Cook	Methamphetamine (µg/sample)
Toy	Cook #1	6.4
Toy	Cook #2	0.18
Baby Suit	Cook #1	500
Baby Suit	Cook #2	6.4

These data again indicate that individuals conducting a methamphetamine cook are generally contaminated. During this study, for the first time, we wiped the inside of the SCBA mask immediately after decontamination. In every case, the mask was positive for methamphetamine. At the same time, samples of the arm taken at the time of decontamination were all found to be negative for methamphetamine. The reason for the contamination inside of the SCBA mask is unclear at this time and future studies will attempt to learn more regarding these results.

The data from the toys and the baby suit continue to suggest that methamphetamine contamination of items present at the scene is almost assured These levels appear to be higher than one might expect from a single cook.

Discussion:

This study was conducted in order to determine the potential exposures associated with the clandestine manufacture of methamphetamine using the hypophosphorous manufacturing methods. Based on our sampling, the primary exposures of concern are hydrochloric acid and methamphetamine. The exposure levels for each of these compounds are similar to those associated with a red phosphorous cook. That should not be a surprise since the two types of cooks are very similar. These cooks were conducted by DEA chemists using methodologies that have been observed in the field with no effort to significantly increase the exposures beyond what might be expected. However, the results could vary due to individual technique and the specific reagents utilized.

Hydrogen Chloride:

The levels of hydrogen chloride that were produced during this type of cook ranged from non-detect during the early portion of the cook to levels as high as 400 ppm based on real-time sampling with an ITX multi-gas meter. Drager tube samples taken in the vicinity of the cook during the salting-out portion of the cook indicated acid levels of 4 ppm to 12 ppm, well above the 2 ppm ceiling TLV. Personal exposures to the cook ranged from 0.6 ppm to 4.5 ppm during the entire extraction period and the levels in the cook area at that time ranged from 2.6 ppm to 3.1 ppm. It is expected that, as in the red phosphorous production method, the exposure of greatest consequence during may be hydrogen chloride.

The current ACGIH TLV for hydrogen chloride is a ceiling value of 2 ppm, much lower than the levels that have been found in the previous controlled cooks that we have conducted. The NIOSH Immediately Dangerous to Life and Health (IDLH) level for hydrogen chloride is 50 ppm which close to the levels generated during the salting-out phase conducted during most of our prior controlled cooks.(8)

Exposure to high levels of hydrogen chloride may cause both acute and chronic effects. One individual exposed during a swimming pool cleaning effort developed severe bronchospasm and asthma. Workers exposed to as little as 10 ppm of hydrogen chloride experienced work impairment. Hydrogen chloride is a strong irritant of the eyes, mucous membranes, and skin at levels that are well below the levels that we have measured during our controlled cooks. It would seem likely that individuals exposed to the measured concentrations that we have found would have acute symptoms from the exposure.(10)

Young persons and individuals with pulmonary problems may show much greater effects from a hydrogen chloride exposure than would an individual with an occupational exposure. The reference level proposed by the Colorado Department of Public Health and Environment for hydrogen chloride was set at 0.01 ppm. It is important to realize that this level is likely to be exceeded during production at all clandestine methamphetamine laboratories.

Methamphetamine:

Methamphetamine contamination of buildings employed in the manufacture of methamphetamine has been a common finding during all of our test cooks and in all methamphetamine laboratories that we have investigated. Even labs that had been shut-down several months prior to testing still had high contamination levels of methamphetamine present on many surfaces within the building with samples as high as 16,000 μg/sample and most samples over 25 μg/100 cm^2.

This widespread contamination is due to the aerosolization of the methamphetamine, especially during the salting-out phase. Levels of methamphetamine measured during a previous cook averaged between 4200 μg/m^3 and 5500μg/m^3 for the salting-out portion of the cook. During this cook, we again found relatively high levels of airborne methamphetamine ranging from 680 μg/m^3 to 3,800 μg/m^3. As in the red phosphorous method of production, the majority of the methamphetamine aerosol was produced during the extraction and salting-out phase of the manufacturing process. These levels of airborne methamphetamine resulted in methamphetamine contamination on most surfaces within the cook building. Methamphetamine contamination was measured at all wipe sampling locations. Methamphetamine was also found on the clothes of all of the participants as well as on toys and clothing present in the cook area.

Although the effects of methamphetamine are well known on individuals using the drug, the effects of low level exposures to emergency personnel or other associated individuals are not as well known. It is known that methamphetamine may cause some teratogenic effects and may change behavior in exposed infants. Prenatal exposure to methamphetamine has been shown to cause an increase in pre-term labor, placental abruption, fetal distress, and postpartum hemorrhage. Infants exposed to methamphetamine are generally smaller, have feeding difficulties, and are described as "very slow". Infants born to mothers that have used methamphetamine during pregnancy may have abnormal sleep patterns, poor feeding, tremors, and hypertionia. In some reports, subtle neurological abnormalities have also been found.(11)

Currently, allowable re-occupancy levels for a residence that has been used as a clandestine laboratory range from 0.1μg/ft^2 to 5 μg/ft^2. Most states and local jurisdictions have adopted 1.0 μg/ft^2 or 0.1 μg/100 cm^2. These levels were initially set at the limit of detection for the compound since no safe level has been established. The drug appears to settle out on all surfaces in the area in which the cook is conducted and it is difficult to determine the actual dose of methamphetamine to individuals working within that atmosphere. It is logical to assume that hand contamination will result in oral ingestion, especially in the case of children, but it may also be possible for the drug to penetrate the skin of adults involved in the investigation.

We have also found that police officers handling suspects or children at the scene, for very short periods of time, can become contaminated with methamphetamine. It is possible for these individuals to carry this material away from the scene and to their own families. Since a no-effect level has not been established for this drug, it would seem prudent to minimize exposure to as low as possible.

Conclusions:

This study was designed to identify and measure potential chemical exposures associated with the investigation of clandestine methamphetamine laboratories where the hypophosphorous methodology of manufacturing was utilized. We conducted the study by manufacturing methamphetamine under controlled conditions in two abandoned houses using the hypophosphorous method of manufacture. During the process, chemical emissions were monitored. Based on our sampling results during this study and prior studies, we can make the following conclusions:

- If a methamphetamine cook is being conducted and the hypophosphorous manufacturing method is used, then exposure to levels of hydrogen chloride that exceed current occupational levels are likely.

- During the cook, it is possible that exposures to hydrogen chloride will exceed levels considered by NIOSH to be immediately dangerous to life or health (IDLH).

- Regardless of whether a cook is being conducted at the time of entry, it is likely that most items and individuals in the vicinity of the cook will be contaminated with methamphetamine.

- If a methamphetamine cook has been conducted within a building, chemicals from the cook will have spread not only in the specific area of the cook but throughout the building. This is especially true of hydrogen chloride and methamphetamine.

- If a methamphetamine cook has been conducted within a building, all children within that building are likely to have been exposed to methamphetamine and other chemicals and should be considered as exposed and contaminated.

- If any law enforcement or emergency services personnel are to be entering a building suspected of being a clandestine methamphetamine laboratory, they should enter only with self-contained breathing apparatus and complete skin protection unless it is known that the lab has not been in recent operation and that all of the chemicals are under control. In the opinion of the authors, it is not likely that these conditions will be known prior to entry in most cases. We therefore suggest that all initial entries be made with the PPE previously mentioned.

- After the suspected laboratory is known to be out of operation and the chemicals are in a stable condition, then investigators could reduce the respiratory protection portion of the PPE to a full-face air-purifying respirator with organic vapor, acid gas, and P100 combination cartridges.

- All law enforcement officers and emergency services personnel should be made aware of the high potential for exposure to methamphetamine contamination and trained in methods to reduce the "take home" levels of methamphetamine. Testing at the scene on a periodic basis should be used to verify that personnel are not being contaminated on-scene.

- Decontamination of all items taken out of the suspected laboratory should be conducted. Efforts should be made to reduce contamination transfer outside of the laboratory and periodic testing should be conducted to assure that personnel and items are being adequately decontaminated.

Study Limitations:

This study was conducted under uncontrolled conditions in the field, frequently while wearing PPE, under potentially dangerous conditions. Under these conditions, sampling can be difficult, equipment can malfunction, and exposures can change. Exposures at any investigation will likely depend upon laboratory activity, building ventilation, manufacturing methodology used, equipment utilized, and amounts and types of precursors utilized. Therefore, the exposures detailed in this report may not be identical to those found at actual clandestine cook sites.

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