

Chemical Exposures Associated with Clandestine
Methamphetamine Laboratories Using the Anhydrous Ammonia
Method of Production

By

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The third cook was conducted in Melissa, Texas and was made possible by the Drug Enforcement Administration (DEA) and the Collin County Sheriff's Department who coordinated the cook. David Love and Jim Iwamoto, chemists for the DEA, conducted the cook. Michelle Jong, Rick Smith, and Greg Westfall from the DEA helped with the arrangements as did Billy Lanier, Mike Fichtl and Tim Overby of the Collin County Sheriff's Department. The Melissa, Texas Fire and Police Departments and the Collin County Medics provided security and emergency services.

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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 (FEV₁) 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 anhydrous ammonia method for the illegal production of methamphetamine. The results of the project will be utilized to inform decisions regarding PPE, containment, and medical treatment of individuals involved with these responses.

Anhydrous Ammonia Methodology:

The use of anhydrous ammonia and reactive metals to reduce ephedrine to methamphetamine has been used in the United States since the mid 1990's. This method has been called the "Nazi" method since it was reportedly a method patented by Germany. However, this statement has not been verified and there is a question as to whether or not this method was developed and/or used in Germany.⁽⁴⁾ To date no German patent has been found and the link to the word "Nazi" is obscure.

The anhydrous ammonia method is not the primary method of methamphetamine production in Colorado or California. However, this method appears to be on the increase. It may be the method of choice in the Midwest and in agricultural areas where

anhydrous ammonia is readily available. The anhydrous ammonia method of production is frequently utilized in open areas where the odor of anhydrous ammonia is less of a concern but it can be used in a structure under some conditions without alerting persons within the vicinity. During our testing, we were surprised at how easily the odor could be dispersed under the conditions present during our controlled cook.

The anhydrous ammonia methodology involves the dissolution of pseudoephedrine tablets in a solvent to which is added anhydrous ammonia and a reactive metal such as sodium or lithium. A common way to obtain the metal is by stripping it out of lithium batteries. The solids left over are dissolved in an organic phase and the methamphetamine precipitated using hydrogen chloride gas. The anticipated exposures to individuals using this methodology are anhydrous ammonia, hydrogen chloride gas, methamphetamine, and organic solvents. Since we have not observed high solvent levels in prior testing, we did not sample for organics at these cooks, but levels of organics may at times be high.

The Controlled Cooks:

Lynn Griffin and David Love, chemists at the South Central Laboratory of the Drug Enforcement Administration, conducted the New Mexico cook and David Love and Jim Iwamoto conducted the Texas Cook. They obtained the pseudoephedrine tablets and removed them from the packaging prior to the actual cook. In New Mexico, the lithium was removed from photographic batteries on the morning of the cook. The anhydrous ammonia was supplied by local companies that brought a cylinder to the cook site for use. In New Mexico a total of two cooks were conducted in two abandoned tri-plexes, one in each building. In Texas, one cook was conducted in a residential building. All of the cooks were conducted using full protective clothing and self-contained breathing apparatus.



Figure 1. Obtaining lithium metal from photographic batteries.

Laboratory Methods

Based on information obtained during our previous studies and the materials to be used, we collected air samples for anhydrous ammonia, inorganic acids, and methamphetamine. In addition, surface samples were collected for methamphetamine. All of the samples were sent to Data Chem Laboratories in Salt Lake City, UT for analysis.

Anhydrous ammonia samples were collected using NIOSH Manual of Analytical Method (NMAM) 6015 which uses a treated silica gel tube for collection. The samples were collected at 150 cc per minute using a personal monitoring pump. They were tested using visible absorption spectrophotometry at Data Chem Laboratories and the results reported back to National Jewish Medical and Research Center.

Inorganic acid samples were collected using a silica gel tube and a personal sampling pump calibrated to an approximate flow rate of 200 cc per minute. After sampling, the tubes were capped and sent to Data Chem Laboratories for ion chromatography analysis using NMAN 7903.

Wipe samples for methamphetamine were collected by wiping a specific 100 cm² area with a sterile four inch by four inch (4x4) gauze wipe. These areas had been marked on the surfaces prior to starting the cook. Before entering the cook area, the 4x4 wipes were individually placed into plastic centrifuge tubes. After entering the laboratory, the wipes were taken out of the tubes and wetted with several milliliters of isopropanol prior to sampling. An attempt was made to minimize cross contamination by using separate pairs of gloves for each sample. After sampling, the wipes were put back into the centrifuge tubes and sent to Data Chem Laboratories for analysis. The samples were analyzed using a NIOSH method under development at the laboratory, which enabled the analysis of the samples using gas chromatograph/mass spectrometer (GC/MS). Airborne methamphetamine samples were also taken in the area of the cooks using a sampling cassette containing a 37 mm glass fiber filter.



Figure 2. Using a 100 cm² template to mark a wipe sampling location at the cook site.

In addition to the laboratory samples, real-time data for hydrochloric acid and anhydrous ammonia were obtained using ITX Multi-Gas Monitors (Industrial Scientific Corporation) at the New Mexico cooks. These monitors provide real-time concentrations and data logging that can be used to determine chemical concentrations during the cook. Although it was expected that the monitors would be able to test for the expected high levels of anhydrous ammonia, they were quickly overloaded and the results became inaccurate for the majority of the cook. Industrial Scientific representatives at the cook believed that the anhydrous ammonia overloading would not affect the hydrogen chloride levels but we believe that all information obtained after the overloading is highly suspect.

During the Texas cook, we chose to use Dräger colorimetric tubes obtained from SKC-West, Fullerton, CA. Two tubes were used for ammonia. A Dräger Ammonia 5/a tube (Part # CH20501) was used to observe ammonia levels from 5 to 70 ppm and a Dräger Ammonia 0.5% tube (Part # CH31901) was used to observe ammonia levels from 0.05% to 10% by volume. Dräger Hydrochloric Acid 1/a tubes were used to observe hydrochloric acid concentrations ranging from 1 to 10 ppm.



Figure 3. Sampling location at the New Mexico cook site.

Although most samples were taken as area samples, a number of samples were also taken in the breathing zone of the DEA Chemists. These samples were designed to determine personal exposures during the cook.

Descriptions of the New Mexico Cooks:

Two distinct and separate anhydrous ammonia cooks were conducted at the site. Since the site was located near other occupied buildings, it was our intent to conduct the cooks

in such a way as to limit the travel of anhydrous ammonia off-site. Based on our observations at the scene, it was not difficult to limit the spread of anhydrous ammonia, much to our surprise. Both of the cooks used a Mason jar for the reaction.

The first cook was conducted in the northern-most tri-plex in the kitchen area. The north-facing window in the kitchen was partially open at the beginning of the cook and then sealed with plastic when some ammonia odor was detected on the outside of the building. For all practical purposes, this cook was conducted under the most confined conditions since most windows and doors were closed. An attempt to reduce ammonia levels within the room was made by venting the process into a water container. This methodology did not seem to have much effect since back-pressure reduced the amount of ammonia entering the water container. There was substantial ventilation, however, since the door was frequently opened to allow movement of personnel, the building itself was poorly insulated and a evaporative cooler was open on the roof. The initial opening of the batteries was conducted in this building and the anhydrous ammonia tank was also stored in this area.



Figure 4. The site of cook #1 showing the closed windows and the door. Note the location of the evaporative cooler on the roof.

The cook was conducted on the kitchen counter adjacent to the window. Area samples were collected at that location and across the room on the east-facing wall where a table had been setup. The location across the room was 10 feet from the cook area and 3.5 feet from the floor. Prior to the cook, 8 sampling locations were identified and marked in the room. Three of those locations were sampled prior to starting the cook in order to assure that methamphetamine was not present prior to the cook. The sampling locations were as follows:

Sample #	Location
1A	2.5 feet from the cook and 5.5 feet off the floor
1B	3.5 feet from the cook and 4.5 feet from the floor
1C	16 inches from the cook on the kitchen counter
1D	10 feet from the cook and 5.5 feet from the floor
1E	11 feet from the cook and 5 feet from the floor
1F	11 feet from the cook and on the floor
1G	17.5 feet from the cook and 5 feet from the floor
1H	17 feet from the cook and 5.5 feet from the floor

A diagram of the building and the sampling locations are as follows:

Cook #1: Methamphetamine Wipe Samples

(All Samples are vertical surfaces unless otherwise noted)

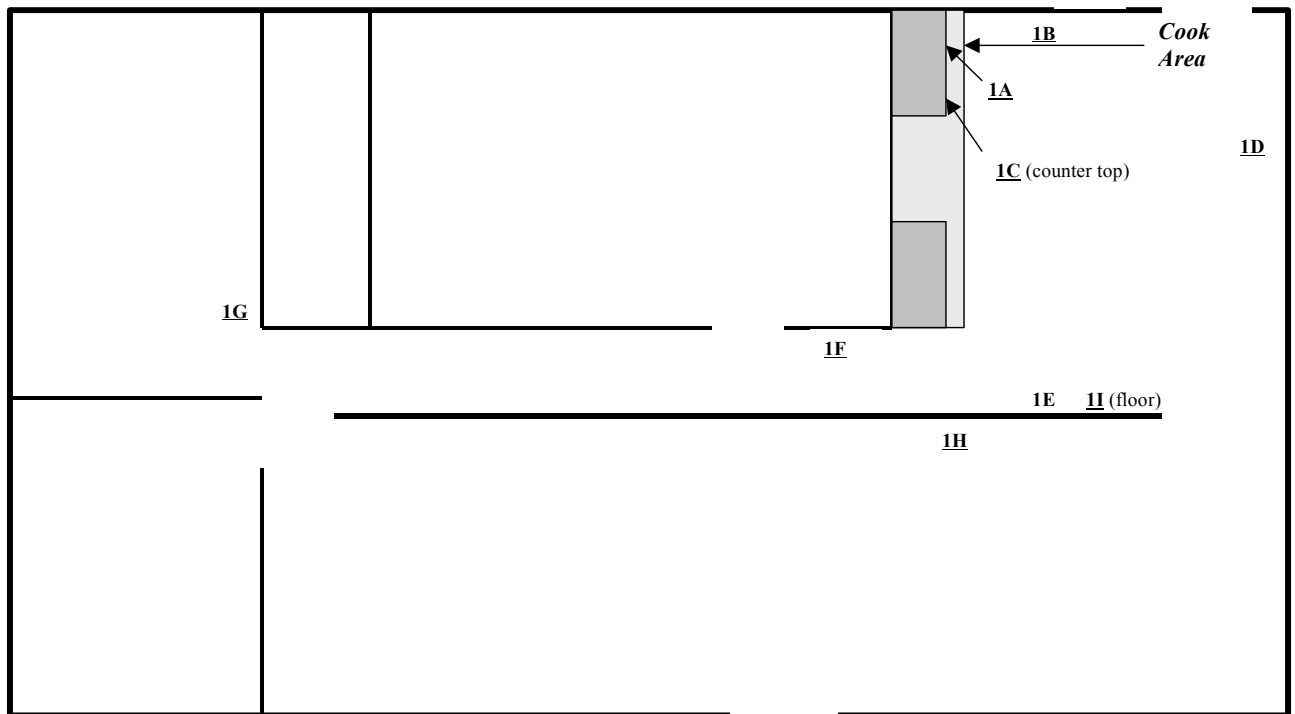




Figure 5. Cook and sampling location for Cook #1.

Cook # 2 was conducted in a separate tri-plex located approximately 50 feet south of the building used in cook #1. It was conducted along the north wall in a bedroom location next to a window that opened into the courtyard. The window to the courtyard was opened and a small household fan was placed into the window. The fan was turned on during the entire manufacturing/sampling process. The rest of the windows were closed and the back window that opened towards an occupied building was sealed shut. This tri-plex, similar to the tri-plex used in Cook #1 was still well ventilated due to ceiling holes as well as other openings.



Figure 6. Setup for Cook #2.

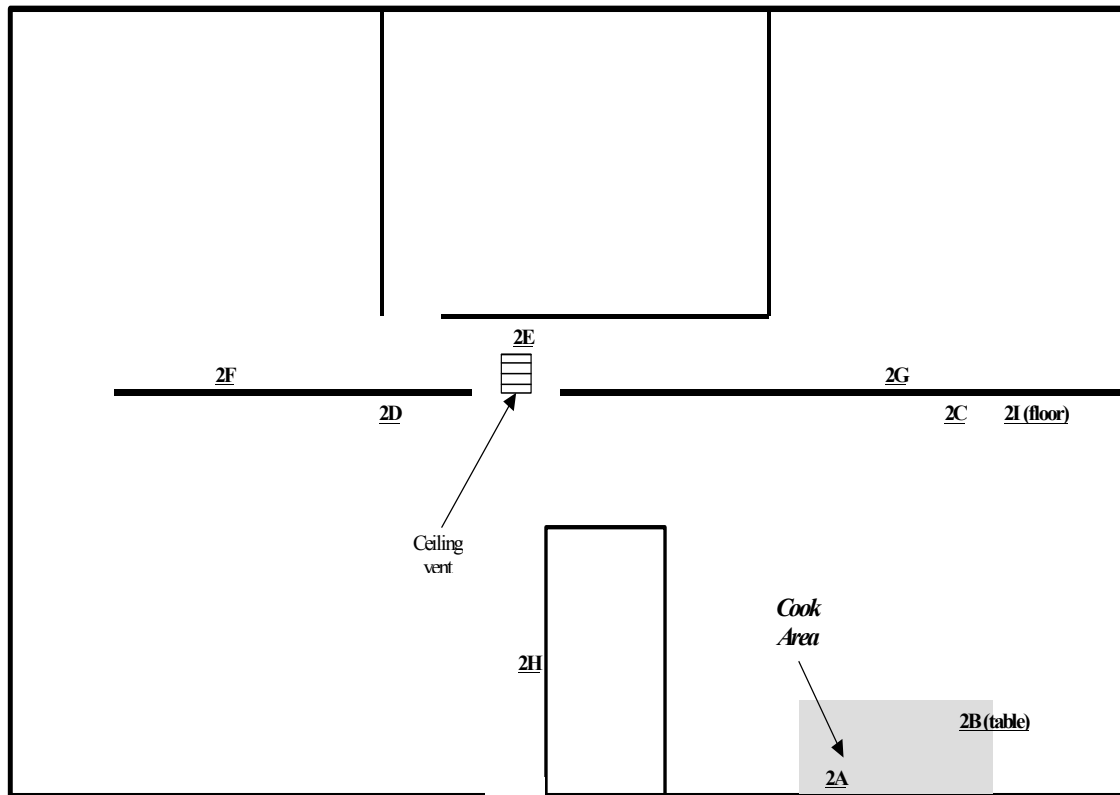
Samples were collected at a distance of 10 feet from the cook on the south wall of the bedroom. Prior to the cook, 9 wipe sample locations were identified and marked in the tri-plex. The locations of these samples were as follows:

Sample #	Location
2A	2 feet from the cook and 5.5 feet off the floor
2B	2 feet from the cook and on the table of the cook
2C	10.5 feet from the cook and 5 feet 8 inches high
2D	15 feet nine inches from the cook and 5.5 feet high
2E	16 feet from the cook and 6 feet high
2F	24 feet from the cook and 5.5 feet high
2G	16 feet from the cook and 5.5 feet high
2H	18 feet from the cook and 5.5 feet high
2I	10.5 feet from the cook on the floor

A diagram of the building and the sampling locations for Cook #2 is as follows:

Cook #2: Methamphetamine Wipe Samples

(All Samples are vertical surfaces unless otherwise noted)



Description of the Texas Cook:

David Love and Jim Iwamoto, chemists at the South Central Laboratory of the Drug Enforcement Administration, conducted this cook. They obtained the pseudoephedrine tablets and the lithium prior to the cook and had the anhydrous ammonia delivered to the site for use. The cook was conducted in a building located near a county landfill that had been abandoned and was used for police and fire department practice sessions. Only one cook was conducted and it was conducted using full protective clothing and self-contained breathing apparatus.

The cook was conducted in a similar manner to the cook in New Mexico except that a shallow glass pan was used in order to evaporate the anhydrous ammonia from the solution. This change enabled a faster evaporation rate than the canning jar used in the New Mexico cook and thus reduced the amount of anhydrous ammonia present when salting-out was conducted.



Figure 7. The cook area showing the glass pan used to speed up the evaporation of the anhydrous ammonia.

The cook was conducted in the back of the house in a kitchen area. The kitchen window was open to the outside and no attempt was made to close off the window. The kitchen opened into a large room that was connected to two other large rooms. Access to all but the adjacent room was sealed off using plastic and all other windows to the rooms were sealed off. The cook area was relatively well ventilated but no effort to increase ventilation (e.g. a window fan) was utilized.



Figure 8. The location of the cook area showing the proximity to the window as well as the position of the sampling pumps.

Samples were taken close to the cook site with the sampling pumps in the window above the cook area. The cook area was located at a height of 5 feet from the floor. A second sampling area was located in the same room at a distance that was approximately 8 feet from the cook and 3 feet from the floor. The third sampling area was located in the adjacent room, approximately 13 feet from the cook and 2.3 feet from the floor.



Figure 9. A picture from the adjacent room sampling area (third sampling area) into the cook area. Notice the door to the adjacent room has been sealed off.

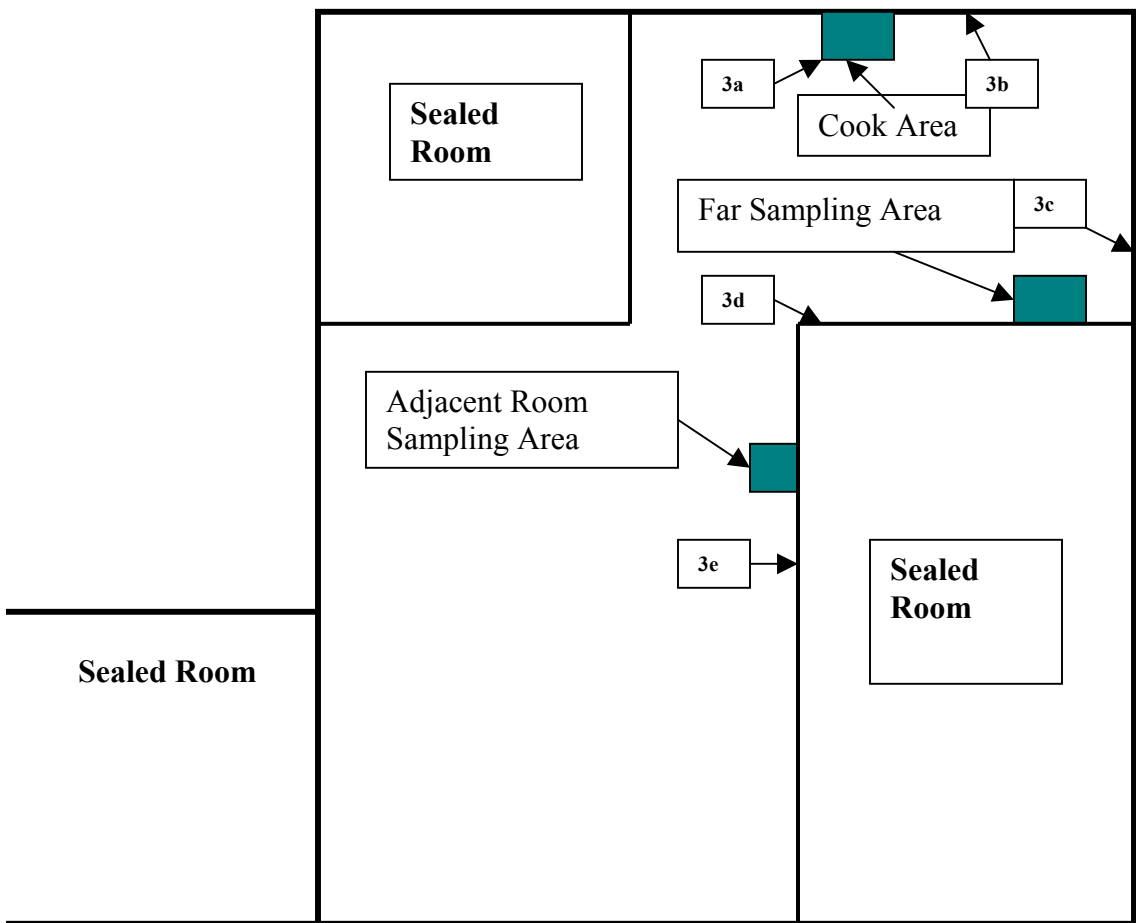


Figure 10. A picture of the house used for the sampling effort in Texas. A plastic door was constructed in the entry-way to reduce airflow into the house.

Prior to the cook, six sampling locations were identified and marked for wipe sampling. All of these locations were sampled prior to the cook, after the cook, and after salting-out. The sampling locations were as follows:

Sample #	Location
3A	10 inches from cook and 2.5 feet off the floor
3B	4.5 feet from the cook and 5.6 feet off the floor
3C	7.9 feet from the cook and 5.9 feet off the floor
3D	6 feet from the cook and 5 feet from the floor
3E	9 feet from the cook and 5.2 feet from the floor
3F	15.5 feet from the cook and 5.5 feet from the floor

Cook #3: Methamphetamine Wipe Sample Locations



Results:

Anhydrous Ammonia Results:

New Mexico cook #1 was initiated at 10:45 am. Within 5 minutes, the ITX Multi-Gas Monitor located at the cook area was over-range and within 16 minutes, all of the monitors in the building were over-range. The maximum level of ammonia recorded was 3348 parts per million (ppm). It is anticipated that this level was reached at the beginning of the cook. The levels of anhydrous ammonia collected for laboratory analysis were also overloaded in two cases. The average amount of ammonia measured during the first three hours of the cook at the actual cook site was in excess of 410 ppm. A significant amount of ammonia was found in the backup section of the tube indicating that the mean ammonia level at the cook area was likely higher than the calculated mean.

At the other side of the kitchen, the mean ammonia levels were found to average 130 ppm for the same period of time and the tube was again found to have ammonia in the backup section indicating that more than 130 ppm may have been present. A personal monitor worn by the DEA chemist indicated that the ammonia level for the initial hour of the first cook was 370 ppm. This sample was collected on the lapel of the DEA chemist during the time period that he was involved with that first.

The real-time samplers at New Mexico Cook #2 were also rapidly overloaded. Real-time samples collected in the air stream of the fan as it exited the building ranged between 50 ppm and 100 ppm during the cook. The anhydrous ammonia measured at the cook area averaged 190 ppm for the two hours of the cook. Very little ammonia was found across the room (<66 ppm) indicating that the simple window fan was effective at reducing anhydrous ammonia concentrations within the room. The personal monitor that was placed in the breathing zone of the DEA chemist recorded a mean anhydrous ammonia level of 130 ppm, less than ½ of the exposure measured in the breathing zone of the chemist during Cook #1.

Although no real-time samplers were used in the Texas Cook #3, the levels of ammonia measured using the Drager tubes ranged from 500 ppm to 2000 ppm. In the cook area during the stirring of the mixture, the levels were generally at 2000 ppm. The levels gradually declined in the cook area if the solution was not agitated and reached a low of 500 ppm. Levels of 500 ppm were generally observed in the other rooms. The outside level at the window was about 50 ppm and the level upwind by the front door was measured to be 4 ppm. The anhydrous ammonia measured at the cook area was 338 ppm during the 101 minutes of the cook and 141 ppm during the 46 minute acidification phase. The levels across the room were 366 ppm during the cook and 268 ppm during the 46 minute acidification phase. The cook was exposed to a mean of 310 ppm even though he was only in the cook area about 50% of the sampling period

A comparison of the mean ammonia levels found at the three cooks are summarized as follows:

Cook #	Cook Area Sample	Across Room Sample	Cook Personal Sample
1	410 ppm	130 ppm	370 ppm
2	190 ppm	<66 ppm	130 ppm
3	338 ppm	366 ppm	310 ppm

These data indicate that the ammonia levels observed during the three cooks were very similar. The levels found during cook #2 were generally lower due to the effect of the fan in the window but the other two cooks both resulted in levels of anhydrous ammonia that exceeded the current standards. The current standards for ammonia are as follows:

Agency	Time Weighted Average	Short Term Exposure Level	Immediately Dangerous to Life and Health
ACGIH	25 ppm	35 ppm	
OSHA	50 ppm		
NIOSH	25 ppm	35 ppm	300 ppm

ACGIH – American Conference of Governmental Industrial Hygienists

OSHA – Occupational Safety and Health Administration

NIOSH – National Institute of Occupational Safety and Health

Hydrochloric Acid Results:

The concentrations of hydrochloric acid were difficult to measure during these cooks. The ITX real-time monitors were unreliable due to the high levels of anhydrous ammonia that over-loaded the real-time analyzers. In addition, the laboratory reported that some chemical was present that interfered with the laboratory analysis using NMAM 7903 which may have resulted in lower levels of hydrochloric acid being reported.

Discussions with DataChem Laboratories suggested that the elevated anhydrous ammonia levels may have interfered with the ion chromatography analysis resulting in very low levels of hydrochloric acid being reported but the actual interfering compound is unknown at this time. Dave Love, a chemist at the DEA South Central Laboratory has hypothesized that the anhydrous ammonia in the room might be reacting with the hydrogen chloride to produce ammonium chloride in the air which was not detected by our equipment. The levels of hydrogen chloride were as follows:

Cook #	Location	Results (ppm)
Cook #1	Cook Area Sample	>0.2 ppm
Cook #1	Far Room Sample	> 0.03 ppm
Cook #1	Personal Sample on Cook	ND
Cook #2	Cook Area Sample	>0.02 ppm
Cook #2	Far Room Sample	>0.03 ppm
Cook #2	Personal Sample on Cook	>0.1 ppm
Cook #3	Cook Area Sample	>0.6 ppm
Cook #3	Far Room Sample	>0.4 ppm
Cook #3	Personal Sample on Cook	>0.7 ppm

ND = None detected

These levels are much lower than we have measured in the past, even though the visible acid mist suggested much higher levels. This observation lends credence to Dave Love’s hypothesis of ammonium chloride being present. The levels measured by the real-time monitors during the New Mexico cooks were also low and ranged from non-detect to 8.7 ppm. Levels of hydrochloric acid were not detected using the Drager tubes in Texas except at the point of acidification.

Airborne Methamphetamine Results:

Airborne methamphetamine results were determined using glass fiber filters to collect the methamphetamine. The filters were desorbed using sulfuric acid and the resultant solution analyzed using GC/MS. In this case, all of the backup pads had methamphetamine present in the pads indicating that some methamphetamine had leaked through the first filter. The results obtained are therefore likely to be less than the actual airborne levels of methamphetamine that were present.

It was hypothesized that, since the anhydrous ammonia method of manufacture keeps the methamphetamine as a base during the initial process, levels of methamphetamine might be picked up during the entire cooking process. This is opposite of what we observed using the red phosphorous method of manufacturing where no detectable methamphetamine was released until the methamphetamine becomes basic. The initial samples that were taken during New Mexico Cook #1 suggested that some methamphetamine may be released during the initial phases of the cook but the majority of the release still occurred during the acid precipitation phase, as in the red phosphorous cooks. The airborne methamphetamine results for Cook #1 were as follows:

Location	Pre-Salting Phase (ug/m³)	Salting Phase (ug/m³)
Cook Area	>10.1	>680
Distant Room Area	> 2.4	>12
Personal Sample on Cook	>15.3	>127

Samples obtained at New Mexico Cook #2 were generally less. This was expected since the Cook #2 area was ventilated to a much higher degree than was the Cook #1 area. The results obtained during Cook #2 were as follows:

Location	Methamphetamine Levels (ug/m³)
Cook Area	>79
Distant Room Area	>2.6
Personal Sample on Cook	>7.6

These levels were generally a factor of 10 below the levels observed in the Cook #1 area although the samples were also taken throughout the entire cook process while the highest samples obtained during Cook #1 were only taken during the salting out phase of the cook. The time sampled was roughly twice that of the samples taken during Cook #1 and therefore if no methamphetamine was present during the initial phase of the Cook, then the levels would be twice the reported level for just the salting out phase. These levels would still be much lower than the levels found during Cook #1 indicating that the ventilation afforded by the window fan was effective to some degree.

The airborne levels of methamphetamine measured during the Texas Cook #3 were similar to Cook #1 and were as follows:

Location	Pre-Salting Phase (ug/m³)	Salting Phase (ug/m³)
Cook Area	>34	>170
Distant Room Area	>42	>158
Adjacent Room	>29	> 66

These data indicate that methamphetamine is released from all of the anhydrous ammonia cooks at levels that are somewhat lower than those measured during the red phosphorous cooks but for a longer time than was observed during the red phosphorous cooks. This is likely due to the volatility to the methamphetamine when it has a basic pH.

Methamphetamine Wipe Results:

Wipe samples were taken at some of the marked locations prior to the cooks. All of these background samples were found to have no detectable methamphetamine present. Three samples were taken at the New Mexico Cook #1 site immediately after the cook and prior to salting out. These levels were very low and ranged from 0.24 ug/100 cm² to 0.83 ug/100 cm². This data, combined with the data obtained from the airborne methamphetamine samples indicates that, although methamphetamine is airborne during the early phases of an anhydrous ammonia cook, the levels are much lower than those during the salting out phase of the cook. The results of the methamphetamine wipe samples obtained in the Cook #1 area were as follows:

Location #	Pre-Cook Levels	Post Cook Levels	Post Salting Out Levels
1A	ND	0.67 ug/100 cm ²	6.3 ug/100 cm ²
1B	ND	0.83 ug/100 cm ²	0.11 ug/100 cm ²
1C			160 ug/100 cm ²
1D	ND		0.72 ug/100 cm ²
1E	ND	0.24 ug/100 cm ²	1.5 ug/100 cm ²
1F			1.4 ug/100 cm ²
1G			1.2 ug/100 cm ²
1H	ND		0.45 ug/100 cm ²
1I			0.78 ug/100 cm ²

The highest level was obtained at location 1C, which was located on a horizontal surface 16 inches from the cook on the kitchen counter. Most other levels were less than those obtained during previous cooks conducted using the red phosphorous methodology. These data continue to suggest that the airborne methamphetamine levels generated during this cook were less than those observed during our previous red phosphorous cooks.

The results obtained from the Cook #2 site were as follows:

Location #	Pre-Cook Levels	Post Salting Out Levels
2A	ND	1.8 ug/100 cm ²
2B		5.6 ug/100 cm ²
2C	ND	0.26 ug/100 cm ²
2D	ND	0.13 ug/100 cm ²
2E	ND	0.13 ug/100 cm ²
2F	ND	0.29 ug/100 cm ²
2G		0.08 ug/100 cm ²
2H		0.1 ug/100 cm ²
2I		0.15 ug/100 cm ²

These levels are lower than the levels measured at the Cook #1 site, again suggesting that the window fan resulted in lower contamination rates. The highest level was found on the horizontal surface near the cook (2 feet from the cook and on the cook table). The levels found in Cook #2 area were generally about 1/10th of the levels found in the Cook #1 area. Contamination at both cooks was observed, however, at every location sampled indicating that contamination is still widespread.

The results observed from Texas Cook #3 were as follows:

Location #	Pre-Cook Levels	Post Cook Levels	Post Salting Out Levels
3A	ND	26 ug/100 cm ²	26 ug/100 cm ²
3B	ND	0.8 ug/100 cm ²	1.1 ug/100 cm ²
3C	ND	2.4 ug/100 cm ²	2.3 ug/100 cm ²
3D	ND	0.6 ug/100 cm ²	0.9 ug/100 cm ²
3E	ND	1.2 ug/100 cm ²	0.9 ug/100 cm ²
3F	ND	0.7 ug/100 cm ²	0.6 ug/100 cm ²

The highest sample was located at 3A which was at the site of the cook. Each site was wiped at the post cook period and during the post salting phase. In this manner, we were able to tell how much was deposited during each phase. The levels observed during Cook #3 were similar to the levels observed during Cook #1, although all of the sites used in Cook #3 were vertical sites.

During the cook process, we also took wipe samples from both of the DEA Chemists in order to determine if they had become contaminated and to determine our ability to decontaminate them. The results of the sampling were as follows:

DEA Cook	Time Period	Methamphetamine per wipe
Cook A	Post Cook	1.2 ug
Cook A	Post Salting Out	150 ug
Cook A	After Decon	0.43 ug
Cook B	Post Cook	6.5 ug
Cook B	End of Day	58 ug
Cook C	Post Salting Out	1.9 ug
Cook C	After Decon	0.1 ug
Cook D	Post Salting Out	0.3 ug
Cook D	After Decon	0.1 ug

The results for Cook C and Cook D were obtained during Texas Cook #3. The contamination levels were lower for these individuals. This is likely due to the shorter time involved in the salting-out process. The results again indicate that the primary contamination of the cooks occurred during the salting-out phase of the cook and not during the cooking phase. In the case of Cook A, decontamination using dry decontamination methods did appear to result in a low contamination under the PPE. The presence of methamphetamine on all of the DEA cooks after decontamination illustrates the difficulty of completely decontaminating individuals involved with methamphetamine laboratories.



Figure 6. PPE worn by DEA cooks at anhydrous ammonia methamphetamine cook.

Discussion:

The primary chemicals of concern at an anhydrous ammonia methamphetamine cook appear to be anhydrous ammonia, hydrochloric acid, and methamphetamine. During these cooks, we sampled for these three compounds and determined the potential exposure concentrations involved with this method of methamphetamine manufacture. Since the cooks were all conducted on rainy days, the concentrations may be lower than might be expected on a warmer day with less humidity. In addition, the DEA cooks employed some methodologies by which exposures might be lowered. For instance, the cooks used a garden sprayer in which to generate the hydrogen chloride gas for the salting-out phase of the cook. This enabled the cooks to slowly meter out the hydrogen chloride and potentially reduce the concentrations present in the air. Factors such as this may have lowered the exposures measured during the cook relative to the exposures at a cook conducted by “backroom” chemists at an actual clandestine laboratory.

Anhydrous Ammonia:

The amount of anhydrous ammonia measured during the cook was somewhat of a surprise to us since the levels, even as a time-weighted average during the cook, approached or exceeded the Immediately Dangerous to Life and Health Levels (IDLH)

published by NIOSH. Anhydrous ammonia is an extremely irritating compound that poses an inhalation hazard, a dermal hazard, an ingestion hazard, and an ocular and mucous membrane hazard. The compound has a very pungent and suffocating odor that typically drives exposed individuals from the area. It is possible, however, that olfactory fatigue can set in quickly allowing increased exposures to individuals. At concentrations exceeding 50 ppm, individuals may experience nose, throat, eye, mucous membrane, and airway irritation. Extended exposure may cause wheezing, shortness of breath, and chest pain as well as tearing and ocular damage.⁽⁵⁾

Exposure to high levels of anhydrous ammonia (levels exceeding 2500 ppm) have been found to cause severe corneal irritation, difficulty breathing, bronchospasm, chest pain and pulmonary edema in otherwise healthy adults. The pulmonary edema associated with these exposures has been fatal in some instances. Repeated exposure to high levels of anhydrous ammonia may cause chronic cough, bronchitis, asthma, vocal cord dysfunction, reactive airways disease, and lung fibrosis. In some cases, a permanent decrement in pulmonary function has occurred due to anhydrous ammonia exposures. Contact with the liquid state may also cause serious eye injury or blindness as well as skin burns.⁽⁶⁾

The current OSHA Permissible Exposure Level (PEL) is 50 ppm and the ACGIH Threshold Limit Value (TLV) for ammonia is 25 ppm as an eight-hour time-weighted average and 35 ppm as a Short-term exposure level (15 minutes or less no more than 4 times per day).^(7,8) The AIHA Emergency Response Guidelines⁽⁹⁾ suggest that most individuals can be exposed to 25 ppm of ammonia for at least one hour without suffering more than mild, transient health effects (ERPG-1). At 150 ppm, most individuals can be exposed for up to one hour without experiencing any irreversible or serious health effects (ERPG – 2). At an exposure level of less than 750 ppm, most individuals could be exposed for up to one hour and not experience any life threatening health effects.⁽⁹⁾ The current NIOSH Immediately Dangerous to Life and Health Level (IDLH) is listed as 300 ppm.

As indicated by the preceding information, anhydrous ammonia poses a significant potential health risk to exposed individuals. The levels of anhydrous ammonia that we observed during the cook ranged from 130 ppm to over 437 ppm as a time weighted average during the cook. The real-time measurements of anhydrous ammonia were so high that we were unable to obtain a reliable quantification, however the Drager tube readings indicated that levels of ammonia routinely approach 2000 ppm during the initial phases of the operation and may remain at over 500 ppm even in areas distant to the cook. Based on these exposures, it is likely that individuals using this method of manufacturing methamphetamine will be over-exposed to anhydrous ammonia and that they will suffer some symptoms associated with that exposure. There is also a high likelihood that the exposure will approach or exceed the NIOSH IDLH level by a significant margin.

Hydrochloric Acid Mist:

Due to an unknown interference from another compound generated during the cook, the traditional methods that we use for measuring exposure levels to hydrogen chloride did not provide the information that we had expected. Although we saw a visible acid mist present, we did not measure it using either the real-time sensors or the silica gel sampling media. The interfering compound may have been the anhydrous ammonia, which may form ammonium chloride or some other compound present at all three of these cooks. We were only able to document hydrogen chloride levels to approximately 8 ppm using the real-time samplers and to 0.7 ppm from the laboratory samplers.

The current ACGIH TLV for hydrogen chloride is a ceiling value of 2 ppm. The levels that we have observed during the anhydrous ammonia cooks have been much lower than the levels that we found in the previous controlled cooks and do not seem to exceed the current TLV. The NIOSH Immediately Dangerous to Life and Health (IDLH) level for hydrogen chloride is 50 ppm which is being approached by the levels generated during the salting-out phase conducted during most of our prior controlled cooks but do not seem to be exceeded during the anhydrous ammonia 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 used to cook methamphetamine has been a common finding during all of our test cooks and during all potential methamphetamine laboratories that we have investigated. Even labs that had been busted several months prior to testing still had high contamination levels of methamphetamine present on many surfaces within the building. Samples as high as 16,000 ug/sample were found with most samples over 25 ug/100 cm².

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 ug/m³ and 5500 ug/m³ for the salting-out portion of the cook. During this cook, we expected that levels of methamphetamine could be released for the entire cooking process since the methamphetamine was in a base form during the entire process. We did find levels of methamphetamine ranging from 2.4 ug/m³ to 42 ug/m³ in the early stages of the manufacturing process (in comparison to no detectable levels during a red phosphorous cook) but still found the highest levels produced during the salting-out phase (7.6 ug/m³ to > 680 ug/m³). These levels of airborne methamphetamine resulted in methamphetamine contamination on most surfaces within the cook building. Methamphetamine contamination was measured at all of the wipe sampling locations although the wipe sampling results were somewhat lower than those measured at previous red phosphorous cooks.

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 hypertension. 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 0.1 ug/ft² to 5 ug/ft². Most states and local jurisdictions have adopted 0.5 ug/ft² or 0.5 ug/100 cm². These levels were initially set at the limit of detection for the compound since, at this time, no safe level has been established. The drug appears to settle out on all porous 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, therefore, 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 at this time, 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 using the anhydrous ammonia methodology for manufacture. We conducted the study by manufacturing

methamphetamine under controlled conditions, in an abandoned apartment, using the anhydrous ammonia method and monitoring the chemical emissions from the process. Based on our sampling results during this study and other prior studies, we can make the following conclusions:

- If a methamphetamine cook is being conducted and the anhydrous ammonia manufacturing method is used, then exposure to levels of anhydrous ammonia and hydrogen chloride that exceed current occupational levels are likely.
- During the cook, it is likely that exposures to anhydrous ammonia will greatly exceed levels considered by NIOSH to be immediately dangerous to life and 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 were 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 anhydrous ammonia 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 therefore 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. Investigations into anhydrous ammonia labs will require ammonia cartridges as organic vapor cartridges will not protect investigators.
- 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.

The results obtained at this controlled cook are expected to be similar to “normal” exposures at a “typical” clandestine methamphetamine laboratory using this methodology but, in fact, there may not be a “normal” or “typical” laboratory since many manufacturers use significantly higher amounts of precursors in areas with very low ventilation rates. Readers should understand that exposure concentrations under actual conditions may be lower but they may also be much higher.

Although our best methodology and laboratory analysis techniques were utilized during this study, some of the results may have been less accurate than we had hoped. The results of the hydrogen chloride sampling were influenced by a probable interference that made detection of the hydrogen chloride difficult. In addition, the real-time instruments used to measure levels of hydrogen chloride and anhydrous ammonia were overloaded and may not have provided accurate information. The levels reported here may be minimum levels.

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