Chemical Exposures Associated with Clandestine Methamphetamine Laboratories

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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 manufacture and lab seizure. As a result there is very poor information on which to establish appropriate medical treatment plans and 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] 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 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 but this phase 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.

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. The results of the project would be utilized to inform decisions regarding PPE, containment, and medical treatment of individuals involved with these responses.

The six goals of the study were to:

- Determine the primary chemical exposures of concern at clandestine drug laboratory seizures for both the responders and the children present at the laboratory site.

- Determine which phase of the response poses the highest risk for responders, what chemicals responders are exposed to, and to what concentrations they are exposed.

- Investigate the relationship between symptoms reported by the responders and the actual exposures measured at the site.

- Investigate how symptoms observed or reported in children that are present in clandestine drug laboratories, relate to the chemical exposures within the laboratory.

- Determine the appropriate types of personal protective equipment required for the various phases of drug lab seizures based on exposure assessments.

- Determine the appropriate components of a medical monitoring program for first responders based on exposure assessments at illegal drug lab sites.

Project Methodology:

Laboratory Methods

To perform the exposure-monitoring component of this project, it was necessary to:

1. Obtain the samples quickly since there would be a limited time for sampling.
2. Hold samples without loosing information until they could be shipped to the laboratory for analysis.
3. Obtain enough sample so that the laboratory limit of detection for the chemicals of interest were lower than the levels of concern for that chemical.
4. Collect the samples with a minimum of personnel effort.

Based on these criteria, air samples were collected for general hydrocarbons, phosphine, inorganic acids, iodine, and metals. In addition, surface samples were collected for methamphetamine and its precursors. The samples for general hydrocarbons were collected using two different approaches. The first approach involved the use of a summa canister, which is a stainless steel evacuated cylinder that can be used to obtain a volume of air immediately from the area in question. 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 in Salt Lake City for analysis. The samples were analyzed using a gas chromatograph combined with a mass spectrometer (GC/MS) by the United States Environmental Protection Agency (EPA) Method T0-15.

The second general hydrocarbon sampling method was conducted using a carbotrap tubes supplied by Data Chem Laboratories. Thermal desorption tubes consist of multi-layer charcoal sorbents through which a known volume of air is drawn using a flow-calibrated personal sampling pump. These samples were collected at a rate of approximately 50 cubic centimeters (cc) per minute. After sampling, the tubes were packaged in air-tight 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.

Phosphine samples were collected on specially treated silica gel tubes using a personal sampling pump that had been calibrated to an approximate flow rate of 100 cc per minute. The sample tubes were capped and sent to Data Chem Laboratories for analysis using the NIOSH Manual of Analytical Methods (NMAM) 6002. This analysis method uses a manual visible spectrophotometry method of analysis.

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

The inorganic acids 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.

Samples for metals were collected using a 0.8 um, cellulose ester membrane filter and a personal sampling pump calibrated to a flow of approximately 2.0 lpm. After sampling, the filters were packaged and sent to Data Chem Laboratories where they were analyzed by inductively coupled argon plasma using NMAM 7300.

Wipe samples for methamphetamine were collected by wiping a specific area with a sterile four inch by four inch (4x4) gauze wipe. Prior to entering the suspected laboratory, 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 or by wiping the gloves with isopropanol between sampling efforts. 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 GC/MS.

Sampling Scenarios

Three types of sampling scenarios were conducted during the investigation. An initial sampling scenario was conducted at the Colorado Springs Police Laboratory in order to determine the potential levels of chemicals that might be encountered in the field and to determine the effectiveness of the sampling methodology. In this instance, three different methods of methamphetamine manufacture were conducted using the facilities and laboratory hoods present in the police laboratory. Two variations of the red phosphorous method and one hypo-phosphorous cook were conducted. In each case, the sampling devices were installed into the hood where the cook was taking place and positioned so that the highest concentrations of chemicals would be collected.

For each type of cook, samples were taken for inorganic acids, phosphine, metals, and iodine. Summa canisters and thermal desorption tubes for organics were taken in one hood at the end of the cook when the methamphetamine was being dissolved in solvent. Wipe samples for methamphetamine were taken in all of the hoods prior to performing the cooks and after conducting the cooks in order to see if methamphetamine was released during the cook. It was expected that prior contamination did exist since methamphetamine had been manufactured in the laboratory prior to this event.

The second sampling scenario occurred during the investigation of individual clandestine methamphetamine laboratories by law enforcement officers. In these situations sample collection devices were brought into the suspected laboratory immediately after entry by law enforcement officials. Initially samples were taken for organics using both the summa canisters and the thermal desorption tubes. After the first several labs, the use of the summa canister was eliminated since the thermal desorption tubes provided adequate information. Initially samples for airborne iodine, phosphine, inorganic acids, and metals were collected at all of the sites. As the investigation progressed, sampling for elements (metals) was discontinued because sampling results were consistently below the limits of detection for the method. Later, sampling focused on acids, iodine, and phosphine in those laboratories that appeared to have been in operation in the recent past. Because environmental surface samples consistently showed positive results, wipe samples were always collected in each suspected laboratory.

The third sampling scenario involved controlled methamphetamine manufacture conducted in an abandoned house scheduled to be burned by the local fire department. This scenario was intended to simulate exposures during illegal methamphetamine manufacture in a residence. Two areas of the house were designated in which to conduct cooks. In one area, a red phosphorous method was utilized and in the other a hypo-phosphorous method was utilized. Samples were collected both in the area of the cook and at a distance from the cook in order to determine the movement of chemical exposures. Samples for phosphine, inorganic acids, iodine, and organics were taken at all sampling locations. In addition, real-time data for hydrochloric acid and phosphine were also obtained using an ITX Multi-Gas Monitor (Industrial Scientific Corporation) This meter provides real-time monitoring and data logging that can be used to determine chemical concentrations during the cook. Methamphetamine wipe samples were collected from specific locations that were measured to be 100 square centimeters. The samples were taken at three intervals; prior to starting the cooks, after the cooks, and after the salting out process.

Questionnaires

We initially planned to give questionnaires to all of the individuals present at each of the clandestine laboratory investigations as well as at training classes put on by the North Metro Task Force. The two questionnaires were developed and submitted to the National Jewish Institutional Review Board for approval. This approval was obtained but not until a large number of the clandestine laboratories had already been investigated. For this

reason, the questionnaires were only given to participants at North Metro Task Force training sessions. They were handed out by North Metro staff and self-administered by participants in the training class. The questionnaires were collected at the end of the class and returned to National Jewish Staff.

Data Collection

All of the data collected during the study was put into Microsoft Excel Spread Sheets. The spread sheets and the raw data were kept on the computer of the Principal Investigator.

Project Results:

This study was initiated on January 1, 2003 and the research team was ready to respond to any methamphetamine labs by the second week of January, 2003. We purchased all necessary respiratory protection, personal protective equipment, sampling equipment, and established the necessary sampling protocols. The team collected samples at the Colorado Springs Police Laboratory where methamphetamine was manufactured under controlled conditions (laboratory hoods) to evaluate potential exposures. The team responded to a total of 16 suspected clandestine methamphetamine laboratories between January 14, 2003 and May 17, 2003. Samples were also collected at a controlled methamphetamine cook conducted in an abandoned house prior to being destroyed by the Fire Department.

Current Occupational Health Criteria for Sampled Substances

The concentration results for the three primary chemicals for which we sampled were compared to the following standards for occupational exposures:

Compound	OSHA PEL	ACGIH TLV	NIOSH REL
Iodine	Ceiling 1.0 mg/m^3	Ceiling 1.0 mg/m^3	Ceiling 1.0 mg/m^3
Phosphine	0.4 mg/m^3	0.4 mg/m^3	0.4 mg/m^3
Hydrogen Chloride	Ceiling 7.0 mg/m^3	STEL Ceiling 3.0 mg/m^3	Ceiling 7.0 mg/m^3

OSHA PEL – Occupational Safety and Health Admin. Permissible Exposure Level
ACGIH TLV – American Conference of Governmental Industrial Hygienists Threshold Limit Value
NIOSH REL – National Institute of Safety and Occupational Health Recommended Exposure Level
STEL – Short Term Exposure Level

Clandestine Laboratories Sampled

The first sampling effort at a clandestine laboratory was conducted on January 14, 2003 at a local hotel in Westminster, CO. This laboratory was in a hotel room that had likely

been used for several days. Chemicals were present but no cook was in progress during our sampling. The drug manufacturers were out of the room at the time of law enforcement entry.

The second sampling effort was conducted on January 15, 2003 in a private residence. According to law enforcement officers, this home had been used as a drug lab until December 2002. The Health Department had ordered the home vacated and the residence had been closed for some time.

A third sampling effort was conducted on January 16, 2003 in an apartment. This apartment had been identified, by law enforcement officers, as a methamphetamine laboratory and was reportedly remediated.

The fourth sampling effort was conducted on January 17, 2003 in a mobile home. This facility also had some chemicals but the laboratory was not in operation at the time of law enforcement entry.

The fifth sampling effort was conducted at a residence where the methamphetamine laboratory was in a bedroom on the 2nd floor. An area in the bedroom had been used for cooking as evidenced by glassware and stains in the area.

The sixth and seventh sampling efforts were conducted at a trailer park and a motel room. The two laboratories were related since a cook had apparently been conducted at the motel room and then the chemicals moved to the trailer park. The cooking area at the motel had significant iodine staining and it was reported, by law enforcement officers, that there had been an associated explosion.

The eighth sampling effort was conducted in another trailer park. The laboratory was located in the kitchen where a number of chemicals were found as well as significant iodine staining. It was reported that the cook had occurred on the Friday before the Monday raid.

The ninth sampling effort was conducted in a house. There was no evidence of cooking at this house but chemicals and glassware were present. It appeared that the house may have been entered prior to the cook actually occurring.

The tenth site that was sampled was a home. It appeared that a cook had occurred in this home since there were many coffee filters with residues that appeared to be related to methamphetamine manufacture at the location. Upon entry, there was a smoky haze inside of the house but no iodine stains were observed.

Suspected laboratory number twelve was located in at home. Iodine stains and burns were evident in the basement bedroom of the home. Iodine staining was not visible on the walls or ceiling, making it difficult to determine if the home was used to cook methamphetamine. This home may have been used as a small day care facility for family members.

The thirteenth laboratory sampling effort was located in a trailer. Glassware and chemicals to manufacture methamphetamine, and drug paraphernalia were discovered on scene, but no signs of iodine stains or a cook were visible.

The fourteenth site was a trailer. Although no visible smoke or discernable smell was present, officers reported having headaches after removing the suspects from the home. Additionally, officers did not wear any personal protective equipment while in the trailer. Although chemicals to manufacture methamphetamine and drug paraphernalia were present, it is unclear if methamphetamine was manufactured in this residence.

Laboratory number fifteen was located in a residence. This laboratory was unique in this study because the lab was discovered after firefighters extinguished a fire in the residence. Chemicals and glassware used to manufacture methamphetamine were discovered throughout the home.

The sixteenth laboratory was a vehicle that was acquired by the Trinidad Police Department. Officers frequently reported headaches and rashes on the arms and forehead after riding in the vehicle.

In general, none of the suspected clandestine methamphetamine laboratories sampled were active laboratories at the time of sampling. In no case did we enter a structure where chemical agents used for the illegal manufacture of methamphetamine were actually being used at the time of entry. In fact, in most cases there was no evidence that a cook had taken place within the last few hours. This was not totally unexpected since some effort is made by North Metro Task Force officials to conduct law enforcement operations at a time where exposure to chemicals is minimized. However, due to the status of the suspected laboratories during our sampling effort, the chemical exposure results that we have obtained from these laboratories should be considered to be the minimum exposures expected during these operations. Chemical exposures at an operational laboratory would be expected to be much higher as our results from the Colorado Springs Police Department and the controlled cook at the abandoned house have shown.

Colorado Springs Police Department Results:

The sampling scenario conducted at the Colorado Springs Police Department was designed to test the sampling methodologies that had been developed and to determine the order of magnitude of the maximum exposures expected at an operating methamphetamine laboratory. Samples were taken for phosphine, metals, inorganic acids, iodine, organic compounds and methamphetamine.

This sampling was conducted on January 10, 2003 in the criminology laboratory located at the police station. Three methamphetamine cooks were conducted at the facility using a street variation of the Red "P" Method, a DEA laboratory variation of the Red "P" Method, and a hypophosphorous acid method. All of these cooks were conducted in

laboratory hoods and samples were taken so as to obtain worst-case samples. Since the hoods were in operation for much of the time during sampling, the results may not be actual worst-case for the process but, rather worst-case under those conditions.

Inorganic Acid Results

The acid scan that was conducted determined the presence of hydrofluoric acid, hydrochloric acid, hydrobromic acid, phosphoric acid, nitric acid, and sulfuric acid. One concern regarding the methodology used was that the blanks submitted with the actual samples were found to contain low levels of nitric and sulfuric acids. In addition, all of the acids, except hydrobromic, for which we tested were found to be present at the Colorado Springs cooks, even though these acids were not utilized in the cooking process and even though they would not be expected to be present. This may not be a surprise since these tests were conducted in laboratory hoods that have likely been used to contain acids in past experiments. During this cook hydrofluoric acid was found in high concentrations in the laboratory variation of the Red"P" Method but so was phosphoric, nitric, and sulfuric. That particular sample appears to have been contaminated either by acids in the hood or as a background artifact in the silica gel tube. In addition, no phosphoric acid was found in the hypophosphorous acid method, which was somewhat of a surprise.

The primary acid concentrations found at the Colorado Springs Police Department were as follows:

Inorganic Acid Results from the Colorado Springs Police Dept. Methamphetamine Cook

Manufacturing Process	Sulfuric (mg/m^3)	Hydrochloric (mg/m^3)	Phosphoric (mg/m^3)
Street method hood cook	0.02	16.9	ND
Street method hood extraction	ND	ND	ND
Lab Method	0.07	4.5	ND
Hypophosphorous method	0.04	0.12	ND
Street Method salting out	0.04	2.36	ND
Blank	ND	ND	ND
Blank	0.021	ND	ND

The highest acid levels were found during the Street Red "P" Cook. The primary acid found was hydrochloric acid. This is no surprise since hydrochloric acid is used during the salting out portion of the process. It was somewhat of a surprise that hydrochloric acid was found during the cooking phase of both the red phosphorous cook and the hypophosphorous cook. It is believed that the production of hydrochloric acid was likely due to the use of ephedrine chloride for the cook.

The salting out phase was found to generate high levels of hydrogen chloride even though the use of the hydrogen chloride was much more controlled that it would have been in a home laboratory. The current American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Level Value (TLV) for hydrochloric acid is

approximately 3.0 mg/m^3 and is a ceiling value meaning that it can't be exceeded for any amount of time. Levels measured at the controlled cooks ranged from slightly below the current allowable level to approximately five times the allowable level. During an actual cook in a house where poor ventilation is present and generation methods are not as controlled, it is likely that acid levels would be significantly higher than those observed in this experiment.

Phosphine Sampling Results

The results of the samples taken for phosphine were as follows:

Phosphine Samples Collected at the Colorado Springs Police Dept. Cooks

Manufacturing Process	Phosphine (µg/m^3)
Street Cook	362.8
Street Extraction	319.1
Lab Cook	4692
Hypophosphorous Cook	ND
Blank	0.8 ug/sample

The blank corrected phosphine concentrations ranged from a non-detect in the hypophosphorous cook to 4692 µg/m^3 during the laboratory red phosphorous cook. However, the blank for the laboratory samples was found to contain 0.8 ug/sample (Limit of Detection was 0.3 ug/sample). The ACGIH TLV for phosphine is approximately 420 µg/m^3.

Iodine Sampling Results

The results of the iodine samples taken at the Colorado Springs Police Department were as follows:

Iodine Sampling Results at the Colorado Springs P.D. Laboratory

Sample Location	Iodine (mg/m^3)
Street method hood	2.3
Lab method hood	37

The levels of iodine found in the air ranged from 2.3 mg/m^3 to 37 mg/m^3 during the actual cooks. The current TLV for iodine is a ceiling value of 1 mg/m^3 indicating that the levels of iodine found in the controlled cook would have exceeded the current standards

by almost an order of magnitude. This was not a surprise since the color of the gases coming off of the cook suggested that iodine was being released at high levels.

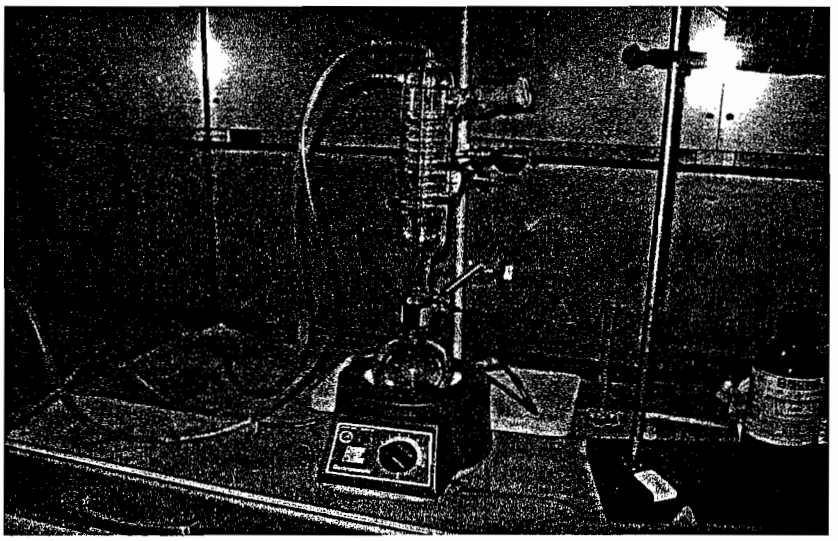

Figure 1: Iodine staining on condenser tube in laboratory hood.

Total Hydrocarbon Results

It was expected that the total hydrocarbon results from this sampling effort would be difficult to interpret due to the fact that the sampling was conducted in a laboratory where a large number of solvents were routinely utilized. Large peaks were found for methyl chloride, isopropanol, chloroform, heptane, methanol, pentane, and a number of aliphatic hydrocarbons. Ethanol, acetone, benzene, toluene, and perchloroethylene were also found to be present in moderate amounts. These compounds would be expected to be common in a chemistry laboratory and none were considered unique to the methamphetamine manufacturing. Chloroform was the solvent that was used to collect the methamphetamine and it was found at high levels in the sampling effort.

Methamphetamine Wipe Sample Results

A number of methamphetamine wipe samples were taken at the Colorado Springs Police Department laboratory cooks. The samples were taken in the upper portion of the hoods and were designed to look at the amount of drug that was liberated during the cook. The levels were influenced by the flow rate of the hood and, in fact, may have been lower than the levels actually produced. All of the hoods had prior methamphetamine levels due to previous cooks in this laboratory. The levels of methamphetamine measured after the cook ranged from 0.78 $\mu g/100\ cm^2$ to 16 $\mu g/100 cm^2$. These levels are well over the 0.5 or 0.1 $\mu g/100\ cm^2$ levels that are currently being used as a standard by many states. The levels are lower, however, than we expected since the cook was confined to the

hood. The lowest methamphetamine levels were found in the hood where the hypophosphorous method was utilized.

We also took wipes of the beaker used to manufacture the methamphetamine and the stirring rod for the cook. The stirring rod had 5200 μg of methamphetamine present and the beaker had 7900 μg of methamphetamine present. Both of these items would be expected to be high.

The results of the wipe samples were as follows:

Methamphetamine Wipe Sample Results from Colorado Springs Police Dept. Cooks

	Analytes in μg/wipe			
Sample Location	**Amphetamine**	**Methamphetamine**	**Ephedrine**	**Pseudoephedrine**
Street Hood Pre Cook	ND	5.4	0.7	2.8
Street Hood Post Cook	3.2	16	0.5	2.4
Lab Method Pre Cook	ND	0.3	0.2	0.3
Lab Method Post Cook	ND	0.8	ND	ND
Hypophosphorous Pre	0.4	7	0.2	1.8
Hypophosphorous Post	0.5	15	0.4	2.6

Drug Lab Response Results:

We responded to a total of 16 suspected clandestine methamphetamine drug laboratories. As previously mentioned, none of these clandestine drug laboratories were in operation at the time of our response. In fact, most of the labs to which we responded were small labs with limited amounts of chemicals present. In only one instance was it reported by law enforcement that a cook had occurred that day. Due to the type of laboratories sampled, it is expected that the levels of chemical exposure that were found would be at the minimum levels that would be expected. For this reason, the exposures that we documented during the laboratory response phase are not applicable to the exposures that should be expected at clandestine laboratories where cooks are in progress or have recently been conducted.

Acid Scan Results

Samples for acids were taken in six of the sixteen laboratories. After the first few laboratories were sampled, it was determined that we would not expect airborne acid to be present unless an actual cook was in progress or had recently been in progress. Initially samples were taken at all of the laboratories but when sample results were consistently below the level of detection, the collection of acid samples was discontinued unless an actual cook was encountered.

Hydrogen chloride was detected in only two of the clandestine labs sampled. In both cases, these were mobile homes. It is not clear that a laboratory had been recently in

operation at either of these locations and the levels of acid found were very low (0.007 mg/m^3 and 0.2 mg/m^3). These levels are fairly low but may suggest that a cook had occurred recently within the suspected laboratory. These results may also represent the lower level of detection for this method. The current ACGIH TLV for hydrogen chloride is a ceiling value of 3 mg/m^3 (2 ppm).

Phosphine Sampling Results

Phosphine is a gas that is liberated during the cooking phase. It is an extremely reactive gas and would not be expected to be present unless a cook was actually occurring. We sampled for phosphine at three of the suspected laboratories and did obtain a positive sample from one lab. The sample result was 358.6 $\mu g/m^3$ which we considered to be relatively high. Since a previous blank had come back with a result of 0.8 ug/sample, it is possible that this method of measuring phosphine is not accurate and that this sample was, indeed, a false positive. It is also possible that somehow an accumulation of phosphine was present within the laboratory.

Iodine Sampling Results

Samples for airborne iodine were taken at 10 of the suspected laboratories. In many of the laboratories, iodine stains were observed on carpeting and on the walls as illustrated below:

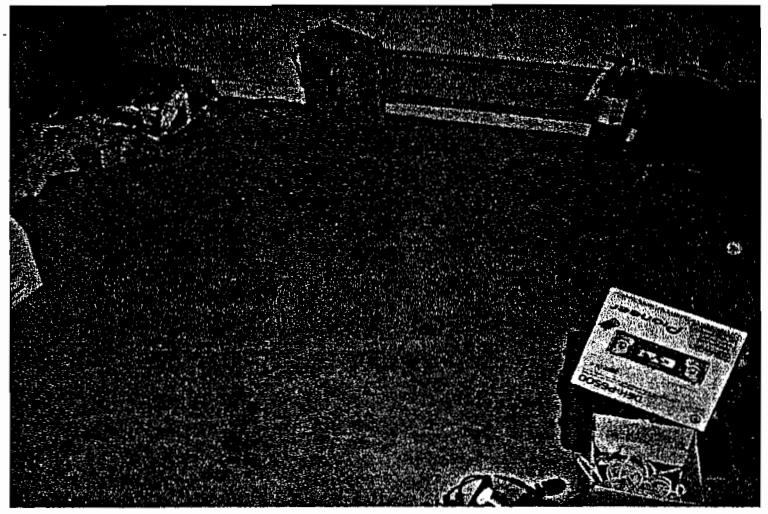

Figure 2: Iodine stains on carpet of suspected methamphetamine laboratory.

It was expected, therefore, that iodine exposures might be high in some of these facilities. The results of the sampling were as follows:

Iodine Sample Results	
Sample Location	**Iodine (mg/m^3)**
Hotel room	ND
Upstairs closet	ND
Main room	ND
Upstairs Bedroom	0.015
Main room	ND
Blank	ND
Hotel room	ND
Main room	0.023
Main room	0.007
Upstairs	0.0079
Main room	ND
Downstairs	ND

Although iodine stains were readily apparent in many of the suspected laboratories, elevated levels of iodine were not present in all of the locations. The levels of iodine that were found were also relatively low with all of the levels well below the current ACGIH TLV of 1.0 mg/m^3 (0.1 ppm) as a ceiling value.

Total Hydrocarbon Results

GC/MS samples taken at the suspected laboratories were difficult to interpret due to the fact that hydrocarbons are commonly utilized in most homes. Peaks were found for isopropanol, methanol, pentane, propene, toluene, heptane and a number of aliphatic hydrocarbons. These compounds are commonly used and would be expected to be found in many homes. Many of the common solvents utilized by clandestine methamphetamine cooks do contain the compounds that were found, however, none of these compounds can be considered to be unique to the production of methamphetamine. In addition, we did not observe any peaks that were exceptionally high except for the isopropanol that we used for a solvent for our methamphetamine wipe samples.

Methamphetamine Wipe Sample Results

Methamphetamine wipe samples were taken at all of the suspected clandestine laboratories. An attempt was made to take all samples in a 100 cm^2 area but in many cases that was not possible. For this reason, the wipe samples should be considered to be in µg/sample results. The results of the sampling efforts are as follows:

Wipe Samples Taken in Methamphetamine Labs

	Analytes in µg/wipe			
Sample Location	**Amphetamine**	**Methamphetamine**	**Ephedrine**	**Pseudoephedrine**
Blind in bedroom	1	120	ND	5.6
Closet Wall	0.36	160	ND	20
Blank	ND	0.2	ND	ND
Counter top by sink	0.1	28	15	1300
Bathroom floor	0.2	9.2	ND	3.7
Floor by kitchen	0.2	39	0.84	150
Red box	0.2	9.1	ND	3.7
Wood table	1.3	920	ND	11
Window blinds	ND	2.1	ND	ND
Ceiling fan	2	94	0.22	0.47
Wall by sink	ND	1.1	ND	ND
Light above sink	0.41	49	15	26
Behind stove	ND	2	ND	0.96
Inside microwave	2	150	ND	0.86
Table on floor by pumps	0.92	520	0.72	81
Table on floor with splashs	0.31	29	1.6	150
Table in bedroom	ND	1.6	ND	0.5
Post in bedroom	ND	1.1	ND	.4
Chandelier in stairwell	0.55	32	0.86	39
TV screen	ND	2.9	ND	4
Sofa	ND	0.84	ND	0.9
Air return	ND	4.1	0.2	0.5
Range hood	0.2	16	ND	0.8
Microwave inside	ND	0.4	0.71	52
Ruined microwave	0.2	9.5	ND	1
Banister	ND	0.8	ND	1.1
Kitchen stove	ND	1.8	6.6	520
Bath exhaust grill	8.6	1600	75	390
Burner in bedroom	0.5	16000	65	670
Ceiling fan	7.1	2500	34	1400
Bedroom dresser	ND	71	2	99
Microwave oven	33	1700	54	4300
Range hood	1	100	2	31
Ceiling fan	4.1	250	2	30
Return air grill	0.9	85	1	48
Night stand	ND	2800	9.3	37
TV table	ND	25	ND	12
Ceiling stain	ND	10000	37	20
Microwave oven	ND	2400	7.2	21
Night stand by bed	ND	62	ND	8
Blank	ND	ND	ND	ND
Bedroom desk	ND	13	5	390
Cold air return	0.5	37	ND	1
Glass pan in bedroom	ND	64	1200	51000
Microwave	ND	37	520	30000
Television screen	0.7	44	ND	4.4
Livingroom table	ND	85	ND	12

Bedroom blinds	ND	13	ND	2
Bedroom dresser	ND	17	ND	3.2
Stained kitchen ceiling	ND	14	ND	5.1
Kitchen counter top	ND	0.91	ND	2.1
Kitchen vent	1.2	24	2	8.4
Microwave	ND	33	7.3	690
Furnace return grill	2.7	320	22	38
Livingroom table	1.4	430	2	14
Inside refrigerator	ND	11	ND	2.8
kitchen stove	ND	12	ND	19
Sink counter	ND	180	120	5700
Return air vent	0.67	450	6.6	99
Recording studio table	ND	250	7.7	120
Kitchen stove	ND	790	280	4000
Livingroom table	ND	120	74	170
Microwave	ND	330	65	4000
Bedroom table	ND	64	2.9	130
Blank	ND	5.7	ND	45
Coffee table	2.4	14	ND	5.8
TV screen	34	300	96	170
Dresser top	ND	3.6	ND	ND
Heater	ND	1.2	ND	ND
Kitchen table	ND	ND	ND	ND
Inside Refrigerator	ND	ND	ND	ND
Kitchen counter	ND	ND	ND	ND
Floor stains	ND	ND	ND	ND
Shelf under window	23	94	17	73
Field Blank	ND	ND	ND	ND
N. Metro Car	ND	ND	ND	ND
Stove	ND	ND	ND	ND
Furnace return grill	ND	10	ND	ND
Bedroom Table	0.43	63	ND	ND
Field Blank	ND	ND	ND	ND
Stove	ND	4	ND	ND
Microwave	1.3	660	ND	8.2
Bedroom Table	ND	650	ND	ND
John's Car	ND	ND	ND	ND
Drug Car	ND	ND	ND	ND
Drug Car	ND	ND	ND	ND
Drug Car	ND	ND	ND	ND
Drug Car	ND	ND	ND	ND
Drug Car	ND	ND	ND	ND
Drug Car	ND	ND	ND	ND

A total of 88 methamphetamine wipe samples were taken in the suspected methamphetamine laboratories. Six of the samples were blanks and only one of the blanks was positive (5.7 µg/wipe). Seventy one samples were positive with a range from 0.4 µg/sample to 16,000 µg/sample. The 16,000 µg/sample was taken in a hotel room where there had been an explosion that coated the ceiling with material. The wipe was of

the material on the ceiling. It was apparent from the results that the drug car seized by the Trinidad Police Department had not been used as a methamphetamine laboratory and data from it was removed from analysis. The mean of the samples, assuming a non-detect to be 0.01 µg/sample, was 584 µg/sample. The median for all of the samples was 37 µg/sample. It should also be noted that in ten out of the 14 labs tested, all of the samples taken in the suspected laboratory were positive.

Many of the locations where methamphetamine was found could not have been contaminated by material falling on a surface. Methamphetamine residue was found not only on tables, but also on air return grates and on ceiling fans. Significant methamphetamine surface contamination was also found in refrigerators, microwaves, and kitchen appliances, suggesting that food contamination is likely to occur. In general, all of the suspected clandestine methamphetamine laboratories had widespread, high levels of methamphetamine in many areas of the house or structure.

Controlled Methamphetamine Cook Results:

The controlled methamphetamine cook was conducted in order to determine the likely exposures present during the cook itself. These exposures would likely represent the exposures to the cook and family residing in the building where the manufacturing was conducted as well as the potential exposures to law enforcement officers entering a suspected lab, during an actual cook. It was expected that these results would generally fall between the worst-case exposures generated in the Colorado Springs Police Department Laboratory and the results found during our sampling of the suspected labs that were not in operation at the time of the investigation.

The building was set up to utilize cooking components that a clandestine cook would be expected to use. The amount of methamphetamine made was, however, less that the amount normally made by cooks, possibly resulting in lower exposure levels. A general cook set-up is shown below:

Figure 3: Methamphetamine lab setup in abandon house.

Three separate controlled cooks were conducted during this portion of the project. A cook using the red phosphorous method was conducted in the kitchen of the abandoned house and two hypophosphorous cooks were conducted in the bedroom. The salting out operations for all of the cooks were conducted in the kitchen. Samples were taken for phosphine, iodine, and hydrogen chloride for all of the operations. Samples were taken in close proximity to the cook (generally immediately above the cook), at a distance away from the cook (10 feet to 15 feet distant), and in the breathing zone of the individuals conducting the cook.

Red Phosphorous Method Results

The results of the chemical sampling during the red phosphorous cook were as follows:

Location	Phosphine (mg/m^3)	Iodine (mg/m^3)	Hydrogen Chloride (mg/m^3)
Above Cook	> 1.32	1.6	14.6
Six feet from Cook	0.37	0.29	0.17
Personal Breathing Zone Sample	0.2	0.42	0.65

These results indicate that the red phosphorous method of cooking methamphetamine generated a significant amount of chemical contamination. The current ACGIH TLV for phosphine is 0.4 mg/m^3 (with a short term exposure limit (STEL) of 1 mg/m^3). The TLV for Iodine is a ceiling value of 1.0 mg/m^3 and the TLV for hydrogen chloride is a ceiling value of 3.0 mg/m^3. As the table above illustrates, the TLV was exceeded for all three chemical substances at the location of the cook and produced significant levels at some distance from the cook. Although the personal samples obtained from the cook were lower than the levels generated at the cook, it should be recognized that the cooks spent a minimal time in the cook area in order to limit exposure. This would not necessarily occur in an actual laboratory.

In addition, we believe that the hydrogen chloride exposure at this stage of the cooking process is the result of the use of ephedrine chloride in the cook. It is possible that if other chemical precursors not containing hydrogen chloride salts were used, the hydrogen chloride content would not be detected.

The samples obtained using the above sampling methods of resulted in a time-weighted average of the concentration of those chemicals during the entire time of the cook. The samples are therefore an average for a period of approximately two hours. The real-time equipment provided information on the peak exposures during that time. The results were as follows:

Location	Peak Phosphine (mg/m^3)	Peak Hydrogen Chloride (mg/m^3)
Close to Cook	4.6	56.2
Distant from Cook	0.67	1.52

In the vicinity of the cook, both the phosphine and the hydrogen chloride are above the current standards, with hydrogen chloride being significantly above the current ACGIH allowable ceiling value. Even at a distance from the cook, the levels measured were significant and approaching current occupational standards.

Hypophosphorous Method Results

The results of the chemical sampling conducted during the initial hypophosphorous cook were as follows:

Location	Phosphine (mg/m^3)	Iodine (mg/m^3)	Hydrogen Chloride (mg/m^3)
Above 1st Cook	0.2	0.19	3.4
Distant from 1st Cook	ND	NA	0.15
Personal Sample	0.28	ND	0.53
Above 2nd Cook	0.5	0.04	Trace
Distant from 2nd Cook	ND	0.03	0.27

ND = Not Detected
NA = Not Available

During this sampling period, the levels of phosphine, iodine and hydrogen chloride were generally less than the levels measured during the red phosphorous cook. Detectable levels of phosphine, iodine, and hydrogen chloride were, however, measured for each of the trials using this method. The exposure levels were generally below the current ACGIH TLV's although the hydrogen chloride concentration was slightly above the TLV ceiling of 3.0 mg/m^3. This elevated hydrogen chloride level may also be due to the use of the ephedrine chloride during the process since no hydrogen chloride was present in the chemicals combined for the cook.

The peak levels of phosphine and hydrogen chloride were also as follows:

Location	Peak Phosphine (mg/m^3)	Peak Hydrogen Chloride (mg/m^3)
Close to Cook	1.19	9.9
Distant from Cook	0.56	5.3

These results again indicate that using the methods that we used, both phosphine and hydrogen chloride do exceed current occupational standards for a period of time. Since the hydrogen chloride is a ceiling TLV, it may not be exceeded for any period of time and thus suggests that over-exposure is likely.

Hydrogen Chloride Results During Salting Out

During the salting out phase of the process, hydrogen chloride was found to be present at high levels. The time-weighted average sample results from the laboratory samples revealed hydrogen chloride levels ranging from 1.2 mg/m^3 to 30.4 mg/m^3 in the areas of the process. The real-time monitor measured a peak hydrogen chloride level of 228 mg/m^3 which is orders of magnitude above the ACGIH ceiling TLV of 3.0 mg/m^3. These levels, even if existing for only a short period of time, could result in significant exposure concerns for the individuals exposed to these levels.

Methamphetamine Wipe Sample Results

Wipe samples were collected on both vertical and horizontal surfaces within the house. Samples were taken before and after the cook in order to determine the contribution of the cooks. Samples were taken in the area of both cooks. The following results were obtained from our sampling:

Cook Type	Location	Pre-Cook (µg/100 cm^2)	Post-Cook (µg/100 cm^2)
Red-P	Vertical wall 113" from cook	ND	10
Red-P	Horiz. Counter 6" from cook	ND	87
Red-P	Horiz. Counter 72" from cook	ND	28
Red-P	Floor 40" from cook	ND	15
Red-P	Wall 63" from cook	ND	20
Red-P	Floor 106" from cook	ND	14
Red-P	Horiz. Cupboard 72" from cook	ND	8.8
Red-P	Cabinet door in bathroom 15 ft. from cook	ND	1.5
Red-P	Cabinet shelf in above	ND	1.7
Hypo	Wall 34" from cook	ND	ND
Hypo	Wall 58 " from cook	ND	ND
Hypo	Wall 44 " from cook	ND	ND
Hypo	Floor 104" from cook	ND	ND
Hypo	Wall 128" from cook	ND	ND
Hypo	Floor in next room 124" from cook	ND	0.05
Hypo	Wall 69" from cook	ND	ND

ND = Not Detectable

As this table indicates, methamphetamine was not detected in any of the samples taken prior to conducting any of the cooks. The area was cleaned and sampled before any of the cooks and a 100 cm^2 area marked off for each area. The areas were sampled before the cook and after the cook. Figure 4 shows a typical vertical surface marked for sampling.

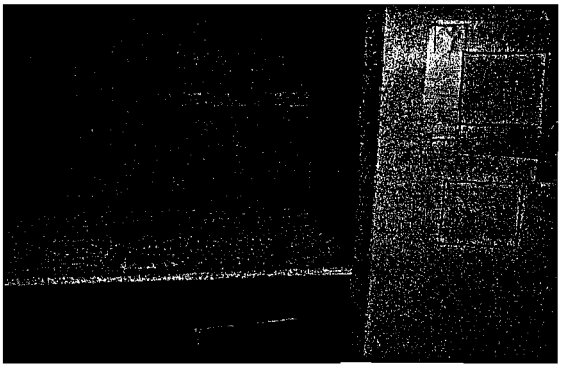

Figure 4: Marked wipe locations taken during controlled cooks.

Based on the information obtained, no methamphetamine was released during the hypophosphorous cook but substantial amounts were released during the red phosphorous cook. Levels were dramatically increased at significant distances from the process. It should also be mentioned that these increases in detectable methamphetamine were also due to only one small cook. It is significant that the increases were observed not only on horizontal surfaces but also on vertical surfaces. These data suggest that the methamphetamine is generated as an aerosol that quickly is dispersed throughout the area of the cook. We believe that this may be the reason for the high levels of methamphetamine that have been found throughout all of the suspected clandestine laboratories that were sampled during this project.

In addition to the area wipes, we also obtained methamphetamine wipe samples from a number of the participants in the project. Wipe samples were taken from the front and head region of the protective suits worn by the cooks and the samplers. The samples were taken in the morning after the cook itself and then in the afternoon after the salting out process. The results of the sampling were as follows:

Time of Sample	**Job Description**	**Methamphetamine (µg/sample**
AM	Hypo Cook	0.04
AM	Red P Cook	0.14
AM	Sampler	ND
AM	Red P Cook (second time)	ND
PM	Sampler	16
PM	Sampler	8.1
PM	Salting Out Cook	18
PM	Blank	0.12

These results indicate that exposure to methamphetamine while sampling and cooking in a methamphetamine lab may result in methamphetamine contamination on clothes and skin. The samples were not taken on hands or feet and, therefore, the levels of contamination are not due to touching or walking on spilled product but rather are due to contamination generated during the cook and sampling.

Questionnaire Results:

A total of 62 questionnaires were returned from participants in North Metro Task Force Training sessions. Forty-nine (79%) of the questionnaires were completed by law enforcement personnel, 8 (13%) by fire fighters, and the rest by public health, social services, and other groups. Fifty (81%) of the respondents were male and 19% were female. The average employee had worked in the current job description for 9.5 years and had been involved with an average of 11 clandestine laboratory investigations.

Sixty-six percent of the respondents had smelled odors associated with the methamphetamine laboratory on at least one occasion, suggesting that there had been a potential for exposure at those laboratory investigations. Although a great number of personnel had smelled odors, only 26% of the respondents reported wearing respirators at laboratory investigations. Since not all of the respondents went into the laboratory areas, it was expected that those that went into the laboratories would have a higher percentage of respirator users. Since 2 respondents did not say if they went into that actual laboratory areas, the total number of respondents for whom we have data was actually 60. Of those, 34 (57%) said that they entered the laboratory area and only 12 (35%) reported wearing respirators. Of the 26 (43%) individuals that stated that they did not enter the laboratory area, only 4 (15%) wore respirators.

Based on the information that we have regarding the possibility of becoming contaminated at a clandestine methamphetamine site, we might expect all individuals to be decontaminated at the site. Of the respondents that entered the laboratories, only 13 (38%) reported being decontaminated at the scene of the investigation. This would suggest that a number of individuals probably leave the site with some contamination.

Thirty-two (52%) of the 62 respondents reported at least one symptom associated with the investigation of clandestine methamphetamine laboratories. Thirty-eight percent (6) of the individuals wearing respirators reported at least one symptom and 59% (27) of the individuals not wearing respirators reported some symptoms. Of the 34 individuals that reported that they entered the laboratories, 20 (59%) reported at least one symptom. Eleven (42%) of the 26 individuals that reported that they did not enter the laboratory areas also reported at least one symptom. The primary symptoms were eye irritation, sore throat, cough, dizziness, and headache. These symptoms are suggestive of the irritational properties of the chemicals involved.

Project Discussion:

This project was conducted with the objective of answering the following questions:

- What are the primary chemical exposures of concern at clandestine drug laboratory seizures for both the responders and the children present at the laboratory site?

- During which phase of the emergency services intervention are the responders exposed to the most chemicals and what are the levels of chemicals to which they are exposed?

- How do the symptoms reported by the responders relate to the exposures measured at the site?

- How do the symptoms observed in children present at clandestine drug laboratories relate to the chemical exposures within the laboratory?

- Based on the potential exposures at clandestine drug laboratory seizures, what personal protective equipment should be worn and during what phases should it be worn?

- How do the symptoms observed in children present at clandestine drug laboratories relate to the chemical exposures within the laboratory?

- Based on the potential exposures at clandestine drug laboratory seizures, what personal protective equipment should be worn and during what phases should it be worn?

- Based upon the potential exposures at the laboratory sites, what components should the medical screening program for responding personnel contain?

Although not all of these questions have been completely answered by this report, we do have a good start on answering many of the questions. We have obtained valuable information on the types and magnitude of chemical exposures associated with cooks involving the red phosphorous method of methamphetamine manufacturing. We have also begun to determine how widespread the contamination during these cooks can become and how it may affect the persons conducting the cook, bystanders (including children and spouses) in the same building, and law enforcement personnel responding to the clandestine laboratory. Based on the information that has been gained from this project, we can shed light on a number of areas such as chemical exposures, expected symptoms, suggested personal protective equipment, and concerns regarding children exposed to these environments.

Chemical Exposures Associated with Clandestine Methamphetamine Laboratories:

Based on our sampling results, the chemical exposures of greatest concern produced during the manufacture of methamphetamine (especially using the red phosphorous

method) consist of phosphine, iodine, hydrogen chloride, solvents, and the drug or its precursors. During the cooking phase, exposure levels of all of these compounds may meet or exceed current occupational exposure guidelines. This is especially true of exposures to phosphine, iodine, and hydrogen chloride. Each of these compounds may exceed the occupational exposure guidelines as set by the Occupational Safety and Health Administration (OSHA) and by the American Conference of Governmental Industrial Hygienists (ACGIH).

Phosphine:

During our sampling efforts at the Colorado Springs Police Department and at our own controlled cook, phosphine was generated during the red phosphorous methamphetamine cooks. Phosphine was produced at levels ranging from 0.17 mg/m^3 to 4.69 mg/m^3 during the cooking phase of the process. It was produced on all occasions during the cook and not just during an overheating event, as some people had suggested. The current ACGIH TLV for phosphine is 0.42 mg/m^3 on an eight-hour time weighted basis with a STEL of 1.4 mg/m^3. The highest level observed was four times the STEL, suggesting that overexposure to phosphine is highly likely.

Phosphine is a severe pulmonary irritant that may cause dyspnea, headache, paresthesia, diplopia, tremor, jaundice, and pulmonary edema. Death from exposure to phosphine has occurred to persons exposed as it was being used as an insecticide.[4] Fatalities thought to be due to phosphine exposure were also linked to a methamphetamine laboratory in Los Angeles, CA where three persons were found dead in a motel room.[5] A laboratory investigator was also reported by Burgess [6] to have developed dizziness, dry cough, headache, and diarrhea, with a delayed onset of cough and dyspnea, after investigating a clandestine laboratory. The exposure was measured at 2.7 ppm phosphine and the duration of exposure was approximately 20 – 30 minutes. These levels are in the same range as the levels measured during our investigation. In workers, phosphine exposure has been shown to cause gastrointestinal, respiratory, and central nervous symptoms at concentrations that are less than 10 ppm.[7]

There are a number of reasons why phosphine intoxication may be more common than reported. Phosphine does have a detectable odor but it may be less readily identified with the presence of the more odorous hydrocarbons present during the cook. In addition, the pulmonary toxicity of phosphine may occur shortly after exposure or it may be delayed for 18 hours or more. These factors may result in fewer reported symptoms, although pulmonary irritation is a common complaint after a clandestine laboratory investigation.

Children and adults that are especially susceptible to pulmonary problems, such as asthmatics, individuals with chronic obstructive pulmonary disease, emphysema, etc, may show significantly greater effects to exposure levels of phosphine that are well below the concentrations allowed in the occupational environment. Unfortunately, at this time, there are no published data regarding acceptable levels of exposure for the general population to phosphine. The effects to these sensitive individuals are, therefore, not known at this time.

Iodine:

Airborne iodine concentrations during the Colorado Springs Police Department Cooks were found to be very high, ranging from 2.3 to 37 mg/m^3. The levels produced during the controlled cooks ranged from 0.29 mg/m^3 to 1.6 mg/m^3. These levels are close to or exceeding the current ACGIH Ceiling TLV of 1.0 mg/m^3. The release of iodine during the red phosphorous cook becomes very obvious when the dark brown effluent is observed. In addition, the walls in many of the cook areas appear to have a brownish yellow stain that is reactive with spray starch forming a dark blue color indicating the presence of iodine.

Airborne iodine is a very heavy halogen vapor that is considered to be more irritating and corrosive than bromine or chlorine gases. In animal studies, iodine vapor has been found to be intensely irritating to mucous membranes, causing damage in both the upper and lower portions of the respiratory tract. Iodine vapors can be an intense irritant to the eyes, mucous membranes and skin and have a steep effects curve in that concentrations of 1 mg/m^3 may cause very little effect while levels of 3 mg/m^3 cause sever irritation.[8]

Although there have been no documented cases of over-exposure to iodine vapor in clandestine methamphetamine laboratories reported in the literature, iodine would be a plausible cause of mucous membrane and eye irritation reported at many of these investigations. Iodine may persist for some time in the walls, carpeting, draperies, etc. present in many of these clandestine laboratories. The fact that it is commonly observed on the walls, even after months of no cooking, suggests that it can be very persistent.

The fact that the iodine is persistent in the environment of the cook is very important to the children that are present in the clandestine laboratories as well as children who inadvertently become residents in a building previously used as a methamphetamine laboratory. Children crawling on contaminated carpeting may pick up high levels of iodine. In addition, based on an evaluation by the Colorado Department of Public Health and Environment, the population-based exposure concentration should be less than 0.001 mg/m^3, three orders of magnitude below the occupational exposure level.[9]

Hydrogen Chloride:

Hydrogen chloride levels were measured during all methamphetamine cooks, including some where hydrogen chloride was not expected. The levels ranged from less than detectable to a time-weighted average of 14.6 mg/m^3. Peak levels measured during the controlled cook ranged as high as 56.2 mg/m^3. The most recent change to the current ACGIH TLV for hydrogen chloride was proposed in 2003 and is a ceiling value of 3.0 mg/m^3, much lower than the levels that have been found during the controlled cooks that we have conducted. In fact, the Immediately Dangerous to Life and Health (IDLH) level for hydrogen chloride is 74.5 mg/m^3 which is being approached by the levels generated during the salting-out phase conducted during the controlled cook.[10]

Exposure to high levels of hydrogen chloride have been known to 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 15 mg/m^3 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 0.02 mg/m^3, a level that is one hundred times lower that the proposed ACGIH TLV.[9] It is important to realize that this level is likely exceeded during production at all clandestine methamphetamine laboratories.

Methamphetamine Exposures:

Methamphetamine contamination of buildings used to cook methamphetamine was a common finding in all of the labs tested. 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 as16,000 µg/sample were found with most samples over 25 $\mu g/100\ cm^2$.

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 borne 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 levels for a residence that has been used as a clandestine laboratory to be re-occupied range from 0.1 $\mu g/ft^2$ to 5 $\mu g/ft^2$. Most states and local jurisdictions have adopted 0.5 $\mu g/ft^2$ or 0.5 $\mu g/100\ cm^2$. These levels have been set primarily at the limit of detection for the compound since, at this time, no safe level has been established. Since the drug appears to settle out on all porous surfaces in the area in which the cook is conducted, it is difficult to determine the actual dose of 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. The State of California has recently begun to study the possibility of skin absorption and its role in methamphetamine exposure.

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 off of the scene and to their own families. Since there has not been a no-effect level established for this drug at this time, it would seem prudent to minimize exposure to as low as possible.

Suggested Personal Protective Equipment Requirements:

Our study has shown that exposures to a variety of chemical compounds may occur during the investigation of clandestine methamphetamine laboratories. During a cook, the exposures at the lab may approach IDLH levels, which by definition may be extremely dangerous to the lives and health of investigating officers. Recent studies have shown that individuals responding to clandestine methamphetamine laboratory investigations have a good chance of being injured. Of 112 methamphetamine-associated hazardous materials events reported to the Centers for Disease Control, 53% resulted in injuries with 155 persons injured. The primary symptoms were respiratory irritation and eye irritation.

During our time responding with law enforcement officers we did not enter an active laboratory and we did not receive any substantive complaints regarding symptoms at any of these investigations. We did, however, hear complaints regarding metallic taste and odors at least two of these investigations. It should be realized, however, that all of the laboratories to which we responded had extremely low chemical exposure levels compared to the levels that we found during our controlled cook. In fact, our testing would suggest that anyone entering an active laboratory without adequate personal protection is likely to be overexposed to phosphine, hydrogen chloride, iodine, and methamphetamine.

Based on our testing, we would suggest that unless a suspected laboratory is assured to be inactive, that the minimum PPE should include total skin protection and the highest level of respiratory protection available. This would mean that all individuals entering a suspected laboratory should wear a positive pressure self-contained breathing apparatus over chemical resistant clothing with chemically resistant gloves and boots. This PPE should be worn in such a manner so as to protect all open skin areas, eyes, and other areas of the body.

If it is known that the laboratory is not in operation and has not been in operation in the recent past, then a lessor degree of respiratory protection may be used. We suggest a minimum of full-face air purifying respirators be used to protect against splash during the investigation. We would also suggest that the respirators be provided with canisters that are protective against acid gases, particulate, and hydrocarbons and that these canisters be discarded after each investigation. Chemical - resistant clothing should be worn by all individuals since methamphetamine contamination in these laboratories is almost assured. Outer clothing should be discarded after leaving the laboratory. Investigators should also

be cautioned not to open sealed bags due to the potential of phosphine release from a "death bag" used to collect the phosphine.

Based on our testing, law enforcement officers should assume that anything present within a suspected methamphetamine laboratory is contaminated with methamphetamine and possible iodine. Therefore, anything taken from the lab should be decontaminated, as should anyone who has entered the laboratory, including law enforcement officers. Training should be provided to assure that officers are aware of the possibilities of contamination, the potential health effects, and the potential to carry exposures out of the laboratory and back to their own families.

Questionnaire Discussion:

The results of the questionnaires handed out at the training sessions were of interest. With only 26% of the individuals involved with clandestine methamphetamine laboratories wearing respirators, there is a great concern that personnel may not be protected well. Many of the respondents were at their first training class and subsequent use of respiratory protection after the class may have been much greater. It is still a concern, however, that many individuals do not wear respiratory protection during these investigations. As our data have shown, exposure to chemicals that may cause severe irritation to mucous membranes are likely at these sites. This is especially true for those individuals actually going into the laboratory area. Since only 35% of the individuals reporting that they entered the laboratory area wore respirators, it is not a surprise that so many individuals reported some symptoms.
Similar studies have suggested that 56% of the individuals involved in clandestine methamphetamine laboratory investigations report symptoms from at least one laboratory. Our data suggests that a similar number (52%) of Colorado emergency services personnel also report symptoms associated with these investigations. The use of respirators seems to reduce this percentage to a degree, but even 38% of the respirator users reported some symptoms. Some of these individuals indicated that the symptoms were experienced when they did not wear respirators but more attention needs to be put upon the use of adequate PPE when responding to these incidents.

Another concern is the number of individuals that report that they enter the laboratory area but are not decontaminated at the scene. Only 38% of the individuals that reported that they entered the laboratory area were decontaminated. Since our data shows that most individuals entering the laboratory area become contaminated, it is likely that methamphetamine contamination makes it out of the laboratory and into personal vehicles, homes, etc. This may result in a widening circle of contamination.

Study Conclusions:

This study was designed to identify and measure potential chemical exposures associated with the investigation of clandestine methamphetamine laboratories. During the study we conducted several tests in laboratory hoods at the Colorado Springs Police Department, sampled 16 suspected drug lab locations, and conducted a controlled cook in a home

under realistic cook conditions. Based on our findings, we make the following conclusions:

- If an actual methamphetamine cook is being conducted and the red phosphorous method is being used, then exposure to levels of phosphine, hydrogen chloride and iodine that exceed current occupational levels are likely.

- If the cook is in process and the salting-out phase is being conducted, hydrogen chloride levels within the area may approach IDLH levels.

- Regardless of whether a cook is being conducted at the time of entry, it is likely that most items and individuals that were in the vicinity of the cook are 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 iodine 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.

- Based on our questionnaire, the use of adequate respiratory protection by personnel entering the laboratory sites is not as high as it should be. Further training is necessary to assure the use of adequate PPE with the hope that the reported symptom rate will decline.

- Based on our questionnaire, over 50% of the officers involved in the investigation of clandestine methamphetamine laboratories have experienced symptoms involved with those investigations. Chemical irritation is the cause of most of the reported symptoms, which seem to decline after the exposure.

- Currently, a low percentage of the personnel involved in clandestine laboratory investigations is decontaminated on site. This is likely to result in methamphetamine contamination spreading outside of the laboratory area and exposing co-workers and family members.

- 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. The most likely compound of concern is the methamphetamine, but iodine and other chemicals may also be transferred.

Study Limitations:

This study was conducted primarily 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. The sampling that we conducted at the suspected clandestine methamphetamine laboratories indicated relatively low exposure conditions but these conditions may not always be present. Exposures at any investigation will likely depend upon laboratory activity, building ventilation, manufacturing methodology used, equipment utilized, and amounts and types of precursors utilized.

The sampling results obtained at the Colorado Springs Police Department were expected to represent high exposures but some manufacturing methodologies combined with a closed-in space may result in significantly higher exposures in some cases. The results obtained at the controlled cook are expected to be similar to "normal" exposures at a "typical" clandestine methamphetamine laboratory but, in fact, there may not be a "normal" or "typical" laboratory since many manufacturers may use significantly higher amounts of precursors in areas with very low ventilation rates. In addition, we only conducted one controlled cook and have yet to look at the influence of larger batches and how they might influence exposure conditions. 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 phosphine sampling were plagued with detectable phosphine levels on the blank samples suggesting that the analysis results may not be accurate. In addition, real-time instruments, such as those used for phosphine and hydrogen chloride in the controlled cook may also give results that are less accurate than are laboratory methods.

References

1. Centers for Disease Control. 2000. MMWR. Public Health Consequences Among First Responders to Emergency Events Associated With Illicit Methamphetamine Laboratories – Selected States, 1996 – 1999. MMWR Weekly, November 17, 2000 / 49(45):1021 –1024.

2. Burgess, J. L., Kovalchick, D.F., Siegel, E.M., Hysong, T.A., McCurdy, S.A. 2002. Medical Surveillance of Clandestine Drug Laboratory Investigators. JOEM 44(2) 184 – 189.

3. Burgess, J.L., Barnhart, s., Checkoway, H. 1996. Investigating Clandestine Drug Laboratories: Adverse Medical Effects in Law Enforcement Personnel. Amer. J. of Indust. Medicine 30:488 – 494.

4. Harger, P.N., Spolyar, L.W. 1958. Toxicity of Phosphine with a Possible Fatality from theis Poison. Arch. Ind. Health 18:497 – 504.

5. Willers-Russo, L.J. 1999. Three Fatalities Involving Phosphine Gas, Produced as a Result of Methamphetamine Manufacturing. J. forensic Sci. 44(3): 647 – 652.

6. Burgess, J.L. 2001. Phosphine Exposure from a Methamphetamine laboratory Investigation. Clinical Toxicology 39(2): 165 – 168.

7. Jones, A.T., Jones, R.C., Longley, E.O. 1964. Environmental and Clinicalo Aspects of Bulk Wheat Fumigation with Aluminum Phosphide. Am. Ind. Hyg. Assoc. J. 25: 375 – 379.

8. ACGIH. 2001. Documentation of the ACGIH TLV's – Iodine. American Conference of Governmental Hygienists. Cincinnati, OH.

9. CDPHE. 2003. Cleanup of Clandestine Methamphetamine Labs: Guidance Document. Colorado Department of Public Health and Environment. July, 2003, Denver, CO.

10. ACGIH. 2003. Documentation of the ACGIH TLV's – Hydrogen Chloride. American Conference of Governmental Hygienists. Cincinnati, OH.

11. Washington Department of Health. 2000. Review of Contamination Levels: Guidelines for Clandestine Drug Lab Cleanup. State of Washington.