HEALTH CONSULTATION

Potential Health Effects at a Clandestine Methamphetamine Laboratory using the Red Phosphorus Production Method

Harrison, Clare County, MICHIGAN

Prepared by

Michigan Department of Community Health
Under a Cooperative Agreement with
Agency for Toxic Substances and Disease Registry

ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	Acute Exposure Guideline Level
ATSDR	Agency for Toxic Substances and Disease Registry
BAYANET	Bay Area Narcotics Enforcement Team
cm^2	centimeters squared (“square centimeters”)
CMDHD	Central Michigan District Health Department
HCl	hydrochloric acid (hydrogen chloride)
HI	hydroiodic acid (hydrogen iodide)
IDLH	Immediately Dangerous to Life and Health
m^3	meters cubed (“cubic meters”)
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
meth	methamphetamine, methamphetamine hydrochloride
mg	milligram
MSP	Michigan State Police
NIOSH	National Institute of Occupational Safety & Health
OSHA	Occupational Safety & Health Administration
PEL	permissible exposure level
ppm	parts per million
RADS	Reactive Airway Dysfunction Syndrome
REL	recommended exposure level
TLV	Threshold Limit Value
µg	microgram
VOC	volatile organic chemical (compound)

FOREWORD

The federal Agency for Toxic Substances and Disease Registry (ATSDR) and the Michigan Department of Community Health (MDCH) have a cooperative agreement for conducting assessments and consultations regarding potential health hazards at toxic chemical contamination sites within the State of Michigan.

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SUMMARY

The Michigan State legislature recently passed a bill (April 2004) that mandates the establishment of re-occupancy standards for former clandestine methamphetamine laboratories ("meth labs"). In order to become more proactive concerning potential health effects from meth labs, the Michigan Department of Community Health (MDCH) initiated an investigation into any past and present adverse health effects following the arrest of the lab residents and seizure of the manufacturing materials in the city of Harrison, Clare County. The purpose of this health consultation is to evaluate exposure pathways associated with the Harrison meth lab and to provide a template for similar health consultations in the future.

The "Red Phosphorus" (Red P) method of methamphetamine manufacturing could be associated with adverse health effects in densely populated buildings, such as apartments and hotels, both during the operational period and after the lab has been busted and dismantled. There appears to be mounting evidence that shows not only are the precursor and intermediary products of meth manufacture dangerous, but that residual contamination could be present near and around the site of the actual "cook" (the term used to refer to the production of a small batches of methamphetamine).

A meth lab employing the Red P method was discovered in the city of Harrison in January 2004, located within an eight-unit apartment building. In addition to leaving residual contamination within the portion of the apartment used for the manufacture of meth, the clandestine drug production is implicated in health effects experienced by several neighbors of the apartment. While there was a complete exposure pathway to other residents of the apartment building, the past hazard was indeterminate in nature, in part due to a lack of environmental data. Subsequent to remediation done in the apartment, currently there is no apparent health hazard at the site.

MDCH will continue to monitor new and developing data on meth labs and the implications for human health and will continue to provide advice on remediation to reduce future health effects from residual contamination. In addition, MDCH will work closely with the MSP and MDEQ to set up appropriate protocols for notification, remediation, and confirmation of clean-up. Toward that end, MDCH will issue more formal remediation guidelines and investigate the establishment of a health-based remediation standard (which would be the first in the nation based on health effects and not analytical limit of detection).

BACKGROUND

Methamphetamine ("meth") is a common drug of abuse which impacts the central nervous system through excessive release of the neurotransmitter dopamine "into areas of the brain that regulate feelings of pleasure" (NIDA 2002). The rise of clandestine manufacturing facilities occurred after methamphetamine became regulated under the 1970 Controlled Substance Act, and, today, there are several different production methods used to illegally make meth (Vandeveld 2004). The predominant manufacturing methods among the small-scale "Mom and Pop" laboratories are the anhydrous ammonia ("Nazi," or Birch reduction method) method and the hydriodic acid/red phosphorus ("Red P" method). Although the Red P method is considered "relatively new" (circa 1982), it was only employed at roughly 20% of all labs dismantled in Michigan from 2002-2003, with the vast majority of the remainder using the "Nazi" method (Saucedo 2004; Skinner 1990).

Any production method of methamphetamine requires four basic components: precursor material, reagent(s), solvent(s), and catalyst(s). The basic steps of the Red P method involves heating a mixture of an ephedrine-bearing precursor substance (like over-the-counter cold medication), red phosphorus, and hydriodic acid, filtering out the unwanted chemicals, and extracting out methamphetamine base precursor after raising the pH of the filtered solution. The final product (methamphetamine hydrochloride salt) is crystallized from the base solution, filtered again, and dried. The final product is usually a powder ranging from white to orange/brown in color and usually more than 95% pure (Skinner 1990). More detailed information regarding meth manufacture using the Red P method can be found later in this report.

The Bay Area Narcotics Enforcement Team (BAYANET), Clare County Sheriff's Department, and a specialized methamphetamine response unit of the MSP recently worked cooperatively to uncover and disrupt a clandestine methamphetamine laboratory ("meth lab") in Harrison, Clare County. The culmination of their efforts led to the interruption and subsequent seizure of the Harrison meth lab on 26 January 2004. This lab was situated in the lower (ground) level of an 8-unit apartment building, located within 1000 feet of the apartment playground, an adult education center, and two elementary schools. Approximately 200 pounds of bulk material and processing equipment were removed from the meth lab by MSP (McClellan 2004). See Appendix A for pictures of the bulk materials removed on 26 January 2004. Samples were taken at that time by the MSP meth unit as evidence for the ongoing criminal investigation and, as such, are not available for public consumption until the case is closed. Following the removal of the bulk materials, an environmental specialty subcontractor was employed by Ferguson Harbor (who in turn is in under contract to the US Drug Enforcement Agency to handle emergency meth lab remediation) to identify and remove the bulk material and processing equipment at the scene.

Site visit

A site investigation was conducted on 30 January 2004 by MDCH and staff from the Central Michigan District Health Department (CMDHD). Pictures were taken of both the exterior and interior of the meth lab (see Appendix B). To ensure the safety of the site investigation team, an initial sweep with a MiniRAE 2000 portable volatile organic chemical (VOC) monitor was performed, starting at the entrance to the apartment and progressing throughout every room. Total VOCs were measured to be between 0.1 and 0.8 ppm throughout the entire two-bedroom apartment. These concentrations are consistent with background exposures and are below any level of concern.

Reconaissance was performed thoughout the entire two-bedroom apartment for signs of meth production, normally seen as staining on walls or other surfaces. It was determined by visual inspection that the "cooking area" was confined to one of the two bedrooms. Duct tape and blankets were used to seal up the window, air vent, and door of the cooking area. A cloth-backed chair in the lab room had dark staining on the cloth that could have been consistent with exposure to an iodine solution (see section on method used and associated hazards). Staining was noted in all wall and ceiling surfaces in the cooking area. There was an obvious difference in color between the exposed wall and sections of the wall that were underneath duct tape (where blankets were fixed to the wall near the door exiting the bedroom). The room (and rest of the apartment with exception of the kitchen) was carpeted and it appeared as if one of the residents actually slept and spent time in the cooking area (as there was a functional computer and a mattress present).

Follow-up interview with residents

A questionnaire was developed in conjunction with the CMDHD and administered to neighbors of the meth lab in April 2004. It was designed to obtain information on possible health effects experienced by other residents of apartment building as well as approximate length of time the lab was in use. From the information that has been received by MDCH at this time, the meth manufacturing likely started at this location sometime in June 2003 and proceeded non-stop through late January 2004, when the lab was dismantled. According to neighbors, exhaust fans in the kitchen and bathroom ran 24 hours a day and window fans exhausted air out of the apartment window during the summer of 2003. The associated odors coming from the meth lab were described as “strong ammonia with some other cleaner, as if you mixed bleach with something else” and were considered strongest at night and on the weekends.

There is anecdotal evidence through this questionnaire implicating the meth lab as being a possible exposure source for transient health effects seen among the apartment building residents and frequent visitors. In fact, a regular visitor to one resident’s apartment complained of headaches that “would clear up when she left” the building. Furthermore, it is possible that some existing medical conditions found among the residents may have been aggravated by air emissions from the meth lab, as these temporary aggravated states were reduced somewhat upon dismantling of the lab in January 2004. More information regarding resident health effects can be found in the following section.

Follow-up with apartment building management

A brief follow-up interview was conducted with the management of the apartment building complex in November 2004. The main purpose of this interview was to follow-up on the MDCH remediation recommendations sent to the property in March 2004 (full text of these recommendations can be found in Appendix F). A secondary purpose was to gather information on new residents of the former lab apartment and whether they had registered any complaints with management regarding living conditions. A single individual without children moved into the apartment following remediation and has registered no complaints with the building’s management.

According the apartment complex manager, the vast majority of MDCH’s recommendations for remediation were followed. All absorbent material (such as clothing, curtains, carpeting, etc.) was removed from the apartment, a layer of sealant was added to the cement floor, and a new carpet pad and carpet was placed on top. All surfaces were scrubbed and/or cleaned to specifications outlined in Appendix F and the walls were re-painted. Furthermore, appliances in the kitchen were also scrubbed and/or cleaned, including the inside of the refrigerator and stove.

There are some uncertainties with the remediation. The extent to which the air ducts/air handling system was cleaned is unknown. Drywall/sheetrock in the cook area was not removed and although the surfaces were repainted, it is unknown whether chemicals related to the meth lab were taken up into the drywall material itself and whether they may leach back out under the right conditions. Given the fact that the drywall was covered in paint while the lab was active and given that the current residents to no include children (who are more likely to have frequent dermal contact with walls, followed by hand-to-mouth behavior), the remediation appears to be sufficient in this case. Finally, there was no post-remedial surface sampling done to verify effectiveness of clean-up. This was not suggested in the letter sent to the building manager nor does MDCH have the regulatory authority to force such actions. Furthermore, the state of Michigan has yet to promulgate clean-up standards for residual meth on surfaces.

DISCUSSION

Environmental Contamination and Other Hazards

Digital pictures that were taken at the time of lab dismantling were provided to MDCH by the Clare County Sheriff. In addition, a phone interview was conducted with the parent company of the firm hired to do emergency remediation (Ferguson Harbor) subsequent to the "lab bust." The photographic evidence and phone interview both corroborate with respect to the materials used and method of production.

The manufacturing process thought to be used at the Harrison lab was the Red P method. Materials found at the Harrison meth lab (and are used in the Red P method) include: Coleman fuel ("white gas"), red phosphorus (in the form of matchbooks), hydrogen chloride (in the form of muriatic acid), isopropyl alcohol (in the form of rubbing alcohol), acetone (in the form of CRC Brakleen® brake parts cleaner), sodium hydroxide (in the form of Red Devil® lye), charcoal lighter fluid, hydrogen peroxide, tincture of iodine, and pseudoephredine (in the form of "over-the-counter" cold medications). In addition, several glass jars containing bilayers of aqueous solution and non-polar solvent were found in the meth lab. The Red P method can produce contaminants including, but not limited to methamphetamine (including both free base and salt formulations), 1,2-dimethyl-pheylaziridine, phenyl-2-propanone, 1-benzyl-3-methylnaphthalene, 1,3-dimethyl-2-phenylnaphthalene, iodine, hydrochloric acid, hydriodic acid, and phosphine gas (CA DTSC 2003) Recent data from "controlled cooks" and actual meth lab sampling revealed that chemical exposures of the greatest concern to the Red P method consist of phosphine, iodine, hydrogen chloride and solvents (including acetone, toluene, charcoal lighter fluid, and Coleman fuel), as well as methamphetamine and its precursors (Martyny et al. 2004).

In addition to the chemical hazards present in this former meth lab, there are biological hazards posed to anyone involved in remediation. The site visit revealed the presence of many hypodermic needles throughout the apartment. Syringes or any other blood-stained materials should always be treated as a biohazard and handled appropriately.

Human Exposure Pathways

To determine whether nearby residents are exposed to contaminants associated with a property, ATSDR and MDCH evaluate the environmental and human components that lead to human exposure. An exposure pathway contains five major elements: 1) a source of contamination, 2) contaminant transport through an environmental medium, 3) a point of exposure, 4) a route of human exposure, and 5) an exposed population.

An exposure pathway is considered a complete pathway if there is evidence that all five of these elements are, have been, or will be present at the property. An exposure pathway is considered a potential pathway if there is no evidence that at least one of these elements are, have been, or will be present at the property.

During the process of producing methamphetamine, there was a complete pathway of exposure. Airborne contaminants from meth production are documented by Martyny et al. (2004) and are discussed in greater detail later in this report. The visible staining on the walls of the cooking area, as seen during the site visit, is evidence that these contaminants dispersed throughout the apartment bedroom. Futhermore, controlled cooks within a multi-unit apartment building setting reported that certain chemicals will spread throughout the entire building, not just the cooking area (Martyny et al. 2004). Therefore, points of exposure existed not only within the cooking area but likely throughout the entire eight-unit apartment building. The residents of the eight units within this particular building are thus considered the exposed population. Past exposures to meth-related airborne chemicals is considered a complete exposure pathway.

Present exposure pathways are no longer complete for the inhalation route, since the chemicals of concern are only airborne during and shortly after active meth production. Prior to remediation, potentially complete exposure pathways existed only through the dermal route (and subsequent ingestion of small amounts of material picked up by dermal contact through "hand to mouth" behavior). Deposition of airborne chemicals and/or contaminant-bearing particulate matter certainly existed in the cooking area. It is this area where the greatest risk generally exists - from dermal contact with chemicals related to meth production. This residual dermal risk can be eliminated through thorough and effective remediation by a trained professional.

Toxicological Evaluation

As mentioned earlier, materials found at the Harrison meth lab included Coleman fuel ("white gas"), red phosphorus, hydrogen chloride, isopropyl alcohol, acetone, toluene, sodium hydroxide, charcoal lighter fluid, hydrogen peroxide, tincture of iodine, and pseudoephedrine. In addition, the red phosphorus method has the potential to generate methamphetamine, 1,2-dimethyl-pheylaziridine, phenyl-2-propanone, 1-benzyl-methylnaphthalene, 1,3-dimethyl-2-phenylnaphthalene, iodine, hydrochloric acid, hydriodic acid, and phosphine gas. Some information related to toxicity is presented here; however, consult Appendix C for more detailed information regarding a particular meth-related chemical.

Coleman Fuel ("white gas") is a complex mixture of primarily aliphatic hydrocarbons produced by distillation of petroleum, usually containing five (5) to nine (9) carbon atoms. This petroleum-based non-polar solvent is used during cooking to extract methamphetamine base

(Turkington 2000). It is heavier than air so it should not be detected above the ground floor of the apartment building in question. Coleman fuel is not expected to persist on indoor surfaces as it is degraded by sunlight and evaporates fairly quickly.

Exposure to Coleman fuel is primarily through inhalation or dermal absorption, especially in the setting of a meth lab. Short-term (one-time, acute) exposure to high concentrations of its vapor can cause light-headedness and depression of the central nervous system, including giddiness, slight nausea, and headache (Salocks and Kaley 2003a). It is immediately irritating to the skin, eyes, and throat and mild tissue damage could be caused due to the mixture's ability to dissolve fats. Chronic exposure can result in eye and skin irritation (and possibly chronic dermatitis), can adversely affect kidney, liver, and respiratory function, and may result in permanent brain damage upon prolonged inhalation exposure (Americhem 2001). Finally, individuals with pre-existing skin disorders, eye problems, or impaired liver, kidney, or respiratory function may be more susceptible to the adverse health effects of Coleman fuel (Mallinckrodt 2001a).

Red phosphorus is combined with elemental iodine (see below) to produce hydriodic acid (HI), which is used to reduce ephedrine or pseudoephedrine to methamphetamine (Salocks and Kaley 2003b). It is usually found in meth labs in the form of matchbook strike plates, although it has many industrial and commercial applications. Like Coleman fuel, its vapor is also heavier than air.

Red phosphorus, in pure form, does not usually represent a significant health hazard; it is essentially non-volatile, insoluble in water, and poorly absorbed (Mallinckrodt 2001b). Red phosphorus may be harmful if absorbed through skin, ingested, or inhaled, and may cause irritation of the skin, eyes, upper respiratory tract, gastrointestinal tract, and mucous membranes (Aldrich 2001b; Central Scientific Company 1994). Inhalation of red phosphorus dust may cause bronchitis (Central Scientific Company 1994). Ingestion of red phosphorus may also cause stomach pains, vomiting, and diarrhea (Aldrich 2001b). Chronic exposure may cause kidney and liver damage, anemia, stomach pains, vomiting, diarrhea, blood disorders, and cardiovascular effects (Acros 2000; Central Scientific Company 1994; Dastech International 2001; Mallinckrodt 2001b).

Iodine is combined with red phosphorus to make hydriodic acid (HI), which is essential ingredient for the conversion of ephedrine to methamphetamine carried out in the Red P production method (Salocks and Kaley 2003c; Turkington 2000). The vapor is heavier than air and will be found close to the floor in any indoor meth lab scenario.

Iodine is an essential element and is required for proper thyroid function. Acute iodine toxicity is due to its irritating properties and can be harmful via all routes of exposure when in elemental form (formulations for medical use generally have low toxicity via dermal and ingestion exposure routes). Exposure to airborne elemental iodine can cause tightness in the chest and can irritate the respiratory system, eyes, and skin while dermal contact can cause skin burns, irritation and rashes (Genium 1999). Severe acute exposures can have adverse effects on the central nervous system (headache, delirium) and cardiovascular system (drop in blood pressure) (Genium 1999).

Chronic ingestion of iodine in excess of dietary requirements can lead to "iodism," which is usually characterized by an unpleasant brassy taste, burning of the mouth and throat, and soreness of the teeth and gums. Chronic ingestion of even larger doses of iodine can lead to an enlargement of the thyroid gland itself, called a "goiter." Human data on chronic inhalation exposures are lacking; however, animal data indicates that chronic inhalation of iodine disrupts thyroid function and reduces the ability of the lungs to take up oxygen. Adverse changes in the lungs of exposed animals include edema, scaling of bronchial epithelium, and bleeding (HSDB 2001a).

Skin or eye contact with iodine can cause irritation and damage and, in rare circumstances, hypersensitivity reactions when skin is exposed. More severe effects are seen when eyes are exposed to elemental iodine vapor.

Hydriodic acid (a solution of hydrogen iodide in water) is used to convert ephedrine to methamphetamine in the Red P production method. Hydrogen iodide is normally found as a colorless gas that is heavier than air, which forms a strong acid (hydriodic acid) when in solution with water. Due to this, corrosive effects can be seen with hydrogen iodide gas comes into contact with moist tissues, like the eyes.

Severe irritation and burns of the skin and eyes are possible after acute dermal exposure to hydrogen iodide, including possible deep burns. Similarly, severe irritation and burns can be caused in the nose, throat and lungs upon acute inhalation exposure, leading to coughing, shortness of breath, sore throat, bronchospasm, persistent pulmonary function abnormalties, and possible delayed pulmonary edema upon very high exposures (HSDB 2003; IPCS 1999; NJ DHSS 2001).

Chronic inhalation exposures to hydriodic acid may cause bronchitis to develop along with cough, phlegm, and/or shortness of breath (NJ DHSS 2001). Chronic dermal exposures could result in dermatitis or skin ulcerations (HSDB 2003)

Sodium hydroxide is one of several alkaline materials commonly referred to as "lye"; in fact, the formulation of sodium hydroxide at the Harrison meth lab was 'Red Devil © Lye.' For the Red P method, sodium hydroxide is used to raise the pH of acidic methamphetamine solutions (Salocks and Kaley 2003d). It is found in many commercial products as both a liquid and a solid, is odorless, and is not volatile.

Acute exposure is very irritating to the eyes, skin, nose, throat, trachea, and lungs and even a single high-level exposure may lead to swelling of the larynx and irreversible obstructive lung disease (ATSDR 2000a). The more dilute the solution is, the longer it takes for initial signs of irritation to appear. Skin and eye exposure can lead to immediate irritation, with possible permanent eye damage (including cataracts, glaucoma, adhesion of the eyelid to the cornea, blindness, and eye loss).

Chronic inhalation exposure to low levels of sodium hydroxide can produce nose and throat irritation, chest pains, shortness of breath, and ulceration of the nasal passages while dermatitis can result from chronic dermal exposure (Salocks and Kaley 2003d). Long-term exposures to moderate levels of airborne sodium hydroxide include persistent hoarseness and type of chemically-induced asthma referred to as “reactive airway dysfunction syndrome” (RADS) (ATSDR 2000a).

Hydrochloric acid/hydrogen chloride is a corrosive gas with an irritating odor that is slightly heavier than air (and thus, is likely found near the floor when released to the environment). Both liquid and gaseous formulations of hydrogen chloride (HCl) can be used to convert liquid free base methamphetamine to solid methamphetamine hydrochloride (“meth”), although gaseous HCl is more effective (Salocks and Kaley 2004; Turkington 2000). The Harrison meth lab had HCl on hand in the form of muriatic acid (a liquid formulation used in swimming pools).

Acute inhalation exposure to HCl may cause irritation and burning of the eyes, nose, throat and larynx, sneezing, coughing, choking, hoarseness, shortness of breath, labored breathing, bronchitis, chest pain, and upper respiratory tract edema (Meditext 2003). Very intense inhalation exposures (roughly 1000 ppm) can lead to death within minutes due to circulatory and respiratory failure. Oral and/or dermal exposures can lead to corrosive effects and severe burns and scarring, with pain, nausea, and vomiting likely upon ingestion of HCl and pain, dermatitis, and ulceration likely upon skin contact.

Chronic inhalation exposures can result in changes in pulmonary function, bronchitis, skin inflammation, decay and erosion of dental enamel, bleeding from the nose and gums, ulceration of the mucous membranes of the nose and mouth, and conjunctivitis (Salocks and Kaley 2004). Sometimes these symptoms may be delayed by more than a day and, in many cases, can lead to permanent damage such as performation of the gastrointestinal tract as well as ocular effects.

Phosphine is an unwanted by-product generated during creation of hydriodic acid and produced when red phosphorus contacts caustics and/or acids, especially in the presence of a metal (Turkington 2000). It has been documented that many deaths among meth cooks have resulted from exposure to this chemical. (In fact, there was a gas mask found along with production materials at the Harrison meth lab so it is presumed that the cooks knew the dangers of using the Red P method.) It is only slightly heavier than air; however, roughly 50% of airborne phosphine is expected to degrade after 24 hours (ATSDR 2002).

Short-term exposure to high concentrations of phosphine may produce adverse effects on the lungs, nervous system, heart, gastrointestinal tract, liver, and kidneys (Salocks and Kaley 2003e). Acute inhalation exposure to high concentrations (over 2 ppm) of phosphine can lead to coughing, severe lung irritation, tightness in the chest, and potential delayed pulmonary edema. Other signs of acute toxicity include rapid and/or irregular heart rate, low blood pressure, shock, nausea, abdominal pain, vomiting, diarrhea, and cardiac arrest (ATSDR 2000b). These symptoms are generally seen within a few hours of exposure with the exception of delayed onset kidney and liver toxicity.

Chronic inhalation exposure to low concentrations (0.5 to 2 ppm) of phosphine can lead to anemia, bronchitis, gastrointestinal symptoms (nausea, vomiting, loss of appetite, abdominal pain, and diarrhea), neurological effects (tremors, double vision, impaired gait, headache, giddiness, and difficulty speaking), liver damage (including jaundice), renal failure, toothache(s), jaw swelling, deterioration of the jaw bones, and spontaneous bone fractures (HSDB 2001b).

Skin and eye contact are generally secondary to inhalation exposures; however, irritation, tearing, pain, swelling, and sensitivity to light (photophobia) can be seen upon eye contact with phosphine gas (HSDB 2001b). Ingestion exposures are generally not expected unless certain waste materials from methamphetamine production are swallowed, which may result in liberation of phosphine gas within the stomach.

Methamphetamine is the desired end product of the cooking process and generally comes in a "free base" (methamphetamine base) or "hydrochloride salt" (methamphetamine hydrochloride) formulation. Oddly enough, methamphetamine is both a Schedule C controlled substance and a pharmaceutical agent, used as a nasal decongestant and to treat obesity and attention deficit disorder with hyperactivity (Salocks and Kaley 2003f).

Meth salt can be inhaled (smoked or snorted), ingested, or injected; the free base can also be injected (Wilburn 2003). Smoking the salt produces the most rapid onset of effects, but biological response is similar via all routes of exposure once absorbed. A number of factors determine biological effects of a given dose, including amount of exposure, age, route of exposure, and repeated exposures.

Acute effects include blurred vision, loss of appetite, weight loss, lightheadedness, increased sweating, urticaria (intense itching of skin), ulcers of the lips and tongue, impotence, changes in libido, chest pain, and unpleasant taste nervousness, hyper-excitability, hyperactivity, irritability, assaultiveness, compulsive or repetitive behavior, euphoria, insomnia, tremor, restlessness, headache, drowsiness, fatigue, exacerbation of motor and phonic tics, and Tourette's syndrome (uncontrolled movement of the head, neck, arms, and legs) (PDR 2002).

Chronic exposure to methamphetamine hydrochloride may cause the following: severe dermatoses, insomnia, irritability, hyperactivity, personality changes, weight loss, poor concentration, grinding of the teeth, ulcers of the lips and tongue, anxiety, fear, compulsive/repetitive behavior, and possible self-injury (PDR 2002).

High level exposures to methamphetamine may also cause cerebral infarction (localized oxygen deprivation, resulting in death of brain tissue and neurological deficit), hemorrhage (bleeding) and may ultimately result in collapse, shock, systemic acidosis (accumulation of acid in the body), coma, and convulsions (MDL 2001).

Health Hazard Issues of Active Red P Meth Labs

Martyny et al (2004) reported that iodine compounds, phosphine, hydrogen chloride, and methamphetamine are the major chemicals of concern for the Red P method. Their study performed some "controlled cooks" using the Red P method and showed some unexpected results. Specifically, the Martyny et al. (2004) study showed that an "active" Red P method (i.e. an active cook using the Red P method) can release:

- Airborne hydrochloric acid concentrations above levels of acute concern (specifically, higher than the Occupational Safety & Health Administration [OSHA] "permissible exposure level" [PEL] ceiling value)
- Airborne phosphine concentrations roughly equivalent to levels of acute concern (specifically, roughly equivalent to the 2nd tier "acute exposure guideline level")
- Airborne iodine concentrations slightly above levels of acute concern (specifically, one sample exceeded the "Immediately Dangerous to Life and Health" value)
- Airborne hydrogen iodide was not tested for by Martyny et al. (2004); however, it could be found in association with airborne iodine. In addition, hydrogen iodide has corrosive effects similar to exposure to hydrogen chloride (hydrochloric acid) when it comes into contact with moist tissues (such as eyes or mucous membranes)

Martyny et al (2004) also took wipe samples both prior to and after the controlled cook for amphetamine, methamphetamine, ephedrine, and pseudoephedrine. These were performed on surfaces as well as lab equipment used during the cook. Wipe samples taken from equipment used during the cook registered 5200 µg (on a beaker used during manufacture) and 7900 µg (on a stirring rod). To put this into perspective, most state remediation standards range from 0.1 to 5 micrograms (µg) per square foot, with most states adopting 0.5 µg /ft^2.

Additionally, almost 100 wipe samples were taken from 14 meth labs in the field and these were also analyzed for amphetamine, methamphetamine, ephedrine, and pseudoephedrine. Of these, 83 samples were positive – ranging from 0.4 µg per sample to 16,000 µg per sample (this higher number was taken in a hotel room where an explosion had occurred during manufacturing). Sixteen (16) of these samples were positive for all four analytes tested for and ten (10) of the fourteen meth labs tested had positive hits for **every** sample taken, with an overall mean of 499 µg per sample across the almost 100 samples. From this data, it can be reasonably assumed that every operational clandestine meth lab will have widespread contamination of amphetamine, methamphetamine, ephedrine, or pseudoephedrine at fairly high concentrations. Furthermore, due to the fact that many high hits were found in refrigerators, microwave ovens, and other kitchen appliances, there is reasonable potential for secondary exposures through consumption of contaminated food or dermal contact with a kitchen appliance.

Martyny et al. (2004) performed one final analysis of note involving a stuffed teddy-bear placed about 12 inches from the location of the controlled cook and later tested for surface pH and methamphetamine content. Surface pH on the stuffed bear indicated a pH of 1, while methamphetamine levels were measured at 3100 and 2100 µg per 100 square centimeters for the outer and inner fur layers that were tested. The results of this test have grave implications for children who come into contact with absorbent items that were sited near an active meth cook, having both corrosive dermal effects from the extremely low pH and dermal absorption effects from the high level of meth on the surface of absorbent items, like the stuffed bear. In addition, this finding has obvious implications for clean-ups involving potentially contaminated absorbent items, such as curtains, carpet, etc.

Health Effects Among Neighbors

As mentioned previously, a questionnaire was developed in conjunction with CMDHD and administered verbally to at least one apartment building resident by CMDHD staff. (See Appendix E for a template of the questionnaire that was used.) Results of this questionnaire that have been received to date provide anecdotal evidence that transient health effects were experienced by not only residents of the building but by frequent visitors as well:

- A 25-year old female mother of two reported she had been treated for migraines for approximately the last 12 years and that the headaches appeared with greater frequency during the period of time she lived directly above the active meth lab. She and her children lived directly above the meth lab for approximately 3-4 months, after which time they moved to a different apartment in the same building.
- The 2-year old male son of the aforementioned mother is currently treated for seizures and cerebral palsy. The medication regime and frequency for his condition were changed in response to "seizures which were becoming uncontrolled" while he lived above the meth lab. This male's sleeping area was directly above the apartment bedroom used to manufacture meth. The severity of the seizures have abated since this family relocated within the building; however, it is unclear whether this is due to a new medication or absence of continued exposure to meth lab chemicals.
- The younger sister of the aforementioned mother was a frequent weekend visitor who also complained of headaches while staying in the apartment building. These headaches would "clear up when she left" the building.
- The aforementioned mother gave birth to a 37-week old female infant in March 2004. The mother and the unborn child were essentially continuously exposed to meth lab chemicals from approximately June 2003 to the end of August 2003 (roughly 3 full months). All potential meth lab exposures appeared to be confined to the third trimester. Birth weight, length and head circumference were all within normal parameters upon delivery.

ATSDR Child Health Initiative

Infants and children are often more vulnerable to exposures than adults in communities faced with environmental contamination. Because children depend completely on adults for risk identification and management decisions, MDCH is committed to evaluating their special interests at the site. One consideration directly related to the risk management decisions made by parents is the fact that children may not necessarily leave an area where they "smell something bad," so they may experience longer exposure times and possibly greater doses than adults.

The effects of the toxicants discussed here on children are generally thought to be similar to the effects on adults. However, children could be especially vulnerable to those exposures that occur near the floor as they breathe air that is closer to the ground than adults. This is especially true of those airborne contaminants that are heavier than air, where concentrations would be expected to be greatest near the floor. (Consult the previous section for those contaminants of concern whose vapor is heavier than air.)

Compared to adults, children have a greater ratio of lung surface area to body weight as well as a greater ratio of respiratory minute volume to body weight (Salocks and Kaley 2003a-f). Due to these differences, it is expected that children will inhale larger doses than adults at any pollutant concentration that is present. If a sufficient dose is inhaled, upper airway blockage and asphyxiation are more likely to occur in children due to the smaller diameter of their airways.

CONCLUSIONS

Clandestine drug laboratories are associated with both acute and long-term health hazards for not only those producing illicit substances but for those who dwell near these secret facilities. There are more specific health threats associated with the "Red Phosphorus" (Red P) production method outlined in this report, including not only the actual ingredients and end product but intermediary chemical and by-products as well. The vast majority of the more severe health threats exist during the active production of methamphetamine (or "cooking") with mainly dermal residual risk remaining once the lab is interrupted and dismantled. However, when cooking is performed in an area with greater population density (such as a hotel, motel, or apartment building), these more severe health threats are more likely to be seen among the innocents surrounding the lab. Along these lines, active Red P meth labs are should be considered public health hazards due to potentially lethal exposures to hydrochloric acid, iodine/hydroiodic acid, and phosphine. The Harrison meth lab is no exception and is also considered to have been a past public health hazard while it was operational.

The meth lab employing the Red P method in the city of Harrison in January 2004 was located within an eight-unit apartment building. In addition to leaving residual contamination within the portion of the apartment used for the manufacture of meth, the clandestine drug production is implicated in health effects experienced by several neighbors of the apartment. While there was a complete exposure pathway to other residents of the apartment building, the residual hazard was indeterminate in nature, in part due to a lack of environmental data. Subsequent to remediation in the apartment unit, there is now no apparent health hazard.

There is weak anecdotal evidence that transient health effects or aggravations of existing conditions were experienced by some apartment residents during the operational phase of the Clare County meth lab. The strongest evidence to support this assertion is the case of the "younger sister" who regularly spent weekends in the apartment building and who complained of headaches that abated when she left the premises. The reported health effects appear to be consistent with acute exposure to volatile organic compounds (such as Coleman fuel), iodine, or phosphine gas. Coleman fuel and iodine are much heavier than air than phosphine, which is only slightly heavier and could be expected to move through an apartment building with prevailing air flow. Furthermore, the work of Martyny et al (2004) demonstrates that phosphine exposures not immediately near the cook could still be at or above the OSHA PEL when the Red P method is used.

It is unclear what adverse health effects, if any, are caused by inhalation exposure to fugitive meth emissions throughout the apartment building. It is possible that these headaches could be caused upon withdrawl from meth; however, the case of the "younger sister" is not consistent with this explanation. Messing (2004) reported that children exposed to meth could be receiving doses similar to those doses used therapeutically and known side effects from such doses include exacerbation of behavioral symptoms and thought disorders in psychotic children as well as exacerbation of motor and phonic tics among children with Tourette's syndrome.

Exposure and medical questionnaire follow-up is critical to understanding whether residents of densely populated buildings – such as apartment buildings, motels, and hotels – may have been adversely affected by the manufacture of meth. Equally as critical is follow-up to determine effectiveness of clean-up; however, the state of Michigan is still working on setting legislative procedures in place to ensure uniform remediation using health-based standards. It is anticipated that these measures will be in place by 2006 as state agencies go through the rule-making process and continue research into defining a health-based exposure standard for meth on surfaces.

RECOMMENDATIONS

Given the potential for exposure in more than resident of the Harrison apartment building, MDCH will continue to be available for consultation by the resident or local health department. In addition, MDCH will continue to monitor new and developing data on meth labs and the implications for human health and will continue to provide advice on remediation to reduce future health effects from residual contamination. In addition, MDCH will work closely with the MSP and MDEQ to set up appropriate protocols for notification, remediation, and confirmation of clean-up. Toward that end, MDCH will issue more formal remediation guidelines and investigate the establishment of a health-based remediation standard (which would be the first in the nation based on health effects and not analytical limit of detection).

Public Health Action Plan

- MDCH will continue to be available for response to public health concerns over potential exposures to meth lab chemicals.
- MDCH will work with local health departments to encourage parents of children exposed to meth lab chemicals to discuss possible sequelae with their family doctors. Similarly, MDCH will provide necessary health education materials regarding residual contamination and health risk as needed.
- MDCH will collaborate with MDEQ to author remediation guidelines for clandestine drug laboratories that will be provided to all local health departments in the state and will be made available on the MDCH web site.
- MDCH will collaborate with MDEQ and MSP to determine roles and responsibilities in meth lab response and will issue a Memorandum of Understanding to formally document these roles and responsibilities.
- MDCH will collaborate with MDEQ to author remedial standards for clandestine drug laboratories. These standards will at the very least include methamphetamine, and possibly other substances used in the production of other illicit substances. These standards will be derived to be protective of the most sensitive populations (which at this time, is thought to be children). It should be noted that, to our knowledge, this is only known attempt in the nation to establish a remedial standard based on health-effects.
- MDCH will consider creating a uniform questionnaire designed to help assess potential exposure and health effects in a "high-density" setting, such as an apartment building or hotel.

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CERTIFICATION

This {site name} Health Consultation was prepared by the Michigan Department of Community Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was begun.

____
Technical Project Officer, SPS, SSAB, DHAC, ATSDR

The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with the findings.

____
Chief, State Program Section, SSAB, DHAC, ATSDR

Appendix A – Digital Pictures of Materials Removed from Meth Lab

Pictures of Bulk Materials found at the Harrison, Clare County Methamphetamine Laboratory
All pictures courtesy of Clare County Sheriff's Department.

Figure A-1. View of bulk materials removed from Harrison meth lab by Michigan State Police. Note the large amount of over-the-counter cold pills in the lower left corner

Figure A-2. Close-up view of bulk materials removed from Harrison meth lab by Michigan State Police. The glass jars on the left were used to store bilayer solutions and improperly sealed with aluminum foil. Chemical reactions were carried out the plastic coolers in the upper right corner.

Figure A-3. View of manufacturing paraphenalia and improperly stored precursor materials removed from Harrison meth lab by Michigan State Police. Note the electrical tape seal on the milk container holding dark-brown liquid and the large box of book matches, which is a source of red phosphorus.

Figure A-4. Close-up view of manufacturing paraphenalia and improperly stored precursor materials removed from Harrison meth lab by Michigan State Police. Note the milk container in the middle of the photo could be holding methamphetamine base. Directly above this is a gas mask that was likely used to protect the cook against phosphine gas.

Appendix B – Digital Pictures of Exterior and Interior of Apartment Building

Pictures of Exterior and Interior of Harrison Methamphetamine Laboratory After Seizure
All pictures courtesy of Michigan Department of Community Health

Figure B-1. View from the front door of the apartment building, looking across the parking lot to an adult education center. Just out of view to the right is one of two near-by elementary schools.

Figure B-2. Close-up of the warning sign placed on window of the apartment by the Michigan State Police.

Figure B-3. Close-up view of a table in the apartment where the lab was located. Most of the paraphernalia on the table was likely pulled out the blue and black security boxes along the left side of the picture.

Figure B-4. Visible staining located on the door jamb of the room which was used as the lab. This is likely staining from the iodine solution used as part of the manufacturing process.

Appendix C - Supplement to the "Toxicological Evaluation" for Methamphetamine Production Materials

Coleman Fuel ("white gas") is a complex mixture of primarily aliphatic hydrocarbons produced by distillation of petroleum, usually containing five (5) to nine (9) carbon atoms. The mixture may contain up to 25% n-hexane and 15% cyclohexane by weight (Calumet 1998). This petroleum-based non-polar solvent is used during cooking to extract methamphetamine base (Turkington 2000). It is heavier than air so it should not be detected above the ground floor of the apartment building in question. Coleman fuel is not expected to persist on indoor surfaces as it is degraded by sunlight and evaporates fairly quickly.

Exposure to Coleman fuel is primarily through inhalation or dermal absorption, especially in the setting of a meth lab. (Ingestion exposures to the ingredients would not be expected and are not covered here.) Short-term (one-time, acute) exposure to high concentrations of its vapor can cause light-headedness and depression of the central nervous system, including giddiness, slight nausea, and headache (Salocks and Kaley 2003a). It is immediately irritating to the skin, eyes, and throat and mild tissue damage could be caused due to the mixture's ability to dissolve fats. Long-term (weeks-months, chronic) exposure to this solvent can lead to peripheral neuropathy (characterized by tingling, numbness, or burning in the feet, legs, and/or hands, as well as muscular weakness and impaired gait) due to the presence of n-hexane in the mixture (HSDB, 2002). In addition, chronic exposure can result in eye and skin irritation (and possibly chronic dermatitis), can adversely affect kidney, liver, and respiratory function, and may result in permanent brain damage upon prolonged inhalation exposure (Americhem 2001). Inhalation of n-hexane may cause drowsiness, headache, fatigue, blurred vision, loss of appetite, polyneuropathy, and paresthesia (i.e. burning or prickling sensation in the fingertips and toes) (Lewis 2002). Finally, individuals with pre-existing skin disorders, eye problems, or impaired liver, kidney, or respiratory function may be more susceptible to the adverse health effects of Coleman fuel (Mallinckrodt 2001a).

Red phosphorus is combined with elemental iodine (see below) to produce hydriodic acid (HI), which is used to reduce ephedrine or pseudoephedrine to methamphetamine (Salocks and Kaley 2003b). It is usually found in meth labs in the form of matchbook strike plates, although it has many industrial and commercial applications. Like Coleman fuel, its vapor is also heavier than air.

Red phosphorus, in pure form, does not usually represent a significant health hazard; it is essentially non-volatile, insoluble in water, and poorly absorbed (Mallinckrodt 2001b). However, red phosphorus may be contaminated with white phosphorus, and symptoms such as nausea, vomiting, abdominal pain, or garlic odor indicate poisoning by the latter (Mallinckrodt 2001b). Therefore, exposure to contaminated red phosphorus may result in adverse effects on health, including irritation of the skin, eyes, lungs, and gastrointestinal tract (Central Scientific Company 1994; Dastech International 2001).

Red phosphorus may be harmful if absorbed through skin, ingested, or inhaled, and may cause irritation of the skin, eyes, upper respiratory tract, gastrointestinal tract, and mucous membranes

(Aldrich 2001b; Central Scientific Company 1994). Inhalation of red phosphorus dust may cause bronchitis (Central Scientific Company 1994). Ingestion of red phosphorus may also cause stomach pains, vomiting, and diarrhea (Aldrich 2001b). Effects may vary from mild irritation to severe destruction of tissue depending on the intensity and duration of exposure (Aldrich 2001b; Dastech International 2001).

Prolonged and/or repeated skin contact may result in dermatitis (Acros 2000). Chronic exposure may cause kidney and liver damage, anemia, stomach pains, vomiting, diarrhea, blood disorders, and cardiovascular effects (Acros 2000; Central Scientific Company 1994; Dastech International 2001; Mallinckrodt 2001b). Chronic ingestion or inhalation may induce systemic phosphorus poisoning. If red phosphorus is contaminated with white phosphorus, chronic ingestion may cause necrosis of the jaw bone ("phossy-jaw") (Mallinckrodt, 2001b).

Iodine is combined with red phosphorus to make hydriodic acid (HI), which is essential ingredient for the conversion of ephedrine to methamphetamine carried out in the Red P production method (Salocks and Kaley 2003c; Turkington 2000). The vapor is heavier than air and will be found close to the floor in any indoor meth lab scenario. It is usually found in the form of iodine crystals or, in the case of the Harrison meth lab, as "tincture of iodine." This formulation is often used as topical antiseptic and is 2% iodine plus 2.4% sodium iodide in 50% ethanol. Iodine can be separated from the tincture formulation (or other iodine solutions) by adding 30% hydrogen peroxide (Turkington 2000). Hydrogen peroxide was also found at the Harrison meth lab and it likely that this substance was used to extract the iodine from the tincture formulation, so it could be used to convert ephedrine to methamphetamine.

Iodine is an essential element and is required for proper thyroid function. Acute iodine toxicity is due to its irritating properties and can be harmful via all routes of exposure when in elemental form (formulations for medical use generally have low toxicity via dermal and ingestion exposure routes). Exposure to airborne elemental iodine can cause tightness in the chest and can irritate the respiratory system, eyes, and skin while dermal contact can cause skin burns, irritation and rashes (Genium 1999). Severe acute exposures can have adverse effects on the central nervous system (headache, delirium) and cardiovascular system (drop in blood pressure) (Genium 1999).

Chronic ingestion of iodine in excess of dietary requirements can lead to "iodism," which is usually characterized by an unpleasant brassy taste, burning of the mouth and throat, and soreness of the teeth and gums. Sometimes increased salivation, inflammation of mucous membranes of the nose (rhinitis), eye and mouth, sneezing, laryngitis, bronchitis, and skin rashes are observed (Hardman et al. 1996). Chronic ingestion of even larger doses of iodine can lead to an enlargement of the thyroid gland itself, called a "goiter." Adverse effects are often due to the corrosive nature of the compound on the gastrointestinal tract and symptoms seen after ingestion include vomiting, a drop in blood pressure, headache, and delirium.

Inhalation of iodine is extremely irritating to the respiratory tract and can result in spasm, inflammation, and fluid accumulation (edema) in the voice box, upper airways, and lungs (Aldrich 2001a). Human data on chronic inhalation exposures are lacking; however, animal data indicates that chronic inhalation of iodine disrupts thyroid function and reduces the ability of the lungs to take up oxygen. Adverse changes in the lungs of exposed animals include edema, scaling of bronchial epithelium, and bleeding (HSDB 2001a).

Skin or eye contact with iodine can cause irritation and damage and, in rare circumstances, hypersensitivity reactions when skin is exposed. More severe effects are seen when eyes are exposed to elemental iodine vapor. In fact, the threshold (0.2 parts per million, or ppm) for eye effects (pain, inflammation, and possible loss of corneal epithelial cells) is roughly four times lower than the odor threshold (0.8 ppm). The implications of this are that meth cooks could be causing eye damage before the olfactory system senses there is a toxic challenge from iodine vapor. These thresholds were frequently exceeded in “controlled cook” data presented by Martyny et al (2004).

Hydriodic acid (a solution of hydrogen iodide in water) is used to convert ephedrine to methamphetamine in the Red P production method. Besides use in clandestine drug labs, hydriodic acid is used as a disinfectant, laboratory reagent, and as raw material for production of (legal) pharmaceuticals and iodine salts (NJ DHSS 2001). Hydrogen iodide is normally found as a colorless gas that is heavier than air, which forms a strong acid (hydriodic acid) when in solution with water. Due to this, corrosive effects can be seen with hydrogen iodide gas comes into contact with moist tissues, like the eyes. Finally, this compound decomposes in light and at room temperatures, liberating hydrogen and elemental iodine vapor (HSDB 2003).

Severe irritation and burns of the skin and eyes are possible after acute dermal exposure to hydrogen iodide, including possible deep burns. Similarly, severe irritation and burns can be caused in the nose, throat and lungs upon acute inhalation exposure, leading to coughing, shortness of breath, sore throat, bronchospasm, persistent pulmonary function abnormalties, and possible delayed pulmonary edema upon very high exposures (HSDB 2003; IPCS 1999; NJ DHSS 2001). Acute ingestion exposures can produce esophageal and stomach burns and possible delayed pyloric strictures and even rarer perforations from the corrosive nature of the compound (HSDB 2003).

Chronic inhalation exposures to hydriodic acid may cause bronchitis to develop along with cough, phlegm, and/or shortness of breath (NJ DHSS 2001). Chronic dermal exposures could result in dermatitis or skin ulcerations (HSDB 2003)

Sodium hydroxide is one of several alkaline materials commonly referred to as “lye”; in fact, the formulation of sodium hydroxide at the Harrison meth lab was ‘Red Devil © Lye.’ It has different functions dependent on the method of production. For the Red P method, sodium hydroxide is used to raise the pH of acidic methamphetamine solutions (Salocks and Kaley 2003d). It is found in many commercial products as both a liquid and a solid, is odorless, and is not volatile. Inhalation exposures are usually associated with mists or dusts containing sodium hydroxide.

Sodium hydroxide is very corrosive and irritating across all routes of exposure. The mechanism of tissue damage is two fold: contact with moisture creates heat and causes thermal burns to exposed tissue while chemical burns result from contact with organic molecules (Salocks and Kaley 2003d). This tissue damage is localized to area of exposure (with the possibility of deep tissue damage to the exposed area) and no systemic toxicity is associated with exposure to sodium hydroxide. A similar corrosive effect can be seen in the mouth, esophagus and stomach following ingestion of sodium hydroxide, with some permanent restrictive scarring possible.

Acute exposure is very irritating to the eyes, skin, nose, throat, trachea, and lungs and even a single high-level exposure may lead to swelling of the larynx and irreversible obstructive lung disease (ATSDR 2000a). The more dilute the solution is, the longer it takes for initial signs of irritation to appear. Skin and eye exposure can lead to immediate irritation, with possible permanent eye damage (including cataracts, glaucoma, adhesion of the eyelid to the cornea, blindness, and eye loss).

Chronic inhalation exposure to low levels of sodium hydroxide can produce nose and throat irritation, chest pains, shortness of breath, and ulceration of the nasal passages while dermatitis can result from chronic dermal exposure (Salocks and Kaley 2003d). Long-term exposures to moderate levels of airborne sodium hydroxide include persistent hoarseness and type of chemically-induced asthma referred to as "reactive airway dysfunction syndrome" (RADS) (ATSDR 2000a).

Hydrochloric acid/hydrogen chloride is a corrosive gas with an irritating odor that is slightly heavier than air (and thus, is likely found near the floor when released to the environment). Both liquid and gaseous formulations of hydrogen chloride (HCl) can be used to convert liquid free base methamphetamine to solid methamphetamine hydrochloride ("meth"), although gaseous HCl is more effective (Salocks and Kaley 2004; Turkington 2000). As a liquid, HCl is generally found in an aqueous solution or in anhydrous form and sotred under pressure in special tanks (similar to those used to store anhydrous ammonia). Liquid formulations of HCl can be found in commercially available toilet bowl cleaners, disinfectants, and swimming pool chemicals (muriatic acid is the formulation used to reduce algal growth in swimming pools). The Harrison meth lab had HCl on hand in the form of muriatic acid. Gaseous HCl can be liberated by combining sulfuric acid with common table salt, and when the gas comes into contact with moisture in the environment, it creates a corrosive and irritating dense white vapor.

Acute inhalation exposure to HCl may cause irritation and burning of the eyes, nose, throat and larynx, sneezing, coughing, choking, hoarseness, shortness of breath, labored breathing, bronchitis, chest pain, and upper respiratory tract edema (Meditext 2003). Mild exposures can resemble an acute viral upper respiratory infection and can occur at concentrations as low as approximately 0.1 ppm (Meditext 2003). Very intense inhalation exposures (roughly 1000 ppm) can lead to death within minutes due to circulatory and respiratory failure. Oral and/or dermal exposures can lead to corrosive effects and severe burns and scarring, with pain, nausea, and vomiting likely upon ingestion of HCl and pain, dermatitis, and ulceration likely upon skin contact. More specifically, oral exposures can result in pain, irritation, nausea, vomiting, thirst, difficulty swallowing, salivation, chills, fever, and shock (Salocks and Kaley 2004).

Chronic inhalation exposures can result in changes in pulmonary function, bronchitis, skin inflammation, decay and erosion of dental enamel, bleeding from the nose and gums, ulceration of the mucous membranes of the nose and mouth, and conjunctivitis (Salocks and Kaley 2004).

Sometimes these symptoms may be delayed by more than a day and, in many cases, can lead to permanent damage such as performation of the gastrointestinal tract as well as ocular effects.

Phosphine is an unwanted by-product generated during creation of hydriodic acid and produced when red phosphorus contacts caustics and/or acids, especially in the presence of a metal (Turkington 2000). Phosphine is commonly used in the electronics and plastics industries and several types of pesticides contain metal phosphides that can liberate phosphine when exposed to moisture (Salocks and Kaley 2003e). It has been documented that many deaths among meth cooks have resulted from exposure to this chemical. (In fact, there was a gas mask found along with production materials at the Harrison meth lab so it is presumed that the cooks knew the dangers of using the Red P method.) Pure phosphine has no odor even at concentrations as high as 200 ppm and any reported odors from this compound are actually due to impurities (IPCS 1998). It is only slightly heavier than air; however, roughly 50% of airborne phosphine is expected to degrade after 24 hours (ATSDR 2002).

Short-term exposure to high concentrations of phosphine may produce adverse effects on the lungs, nervous system, heart, gastrointestinal tract, liver, and kidneys (Salocks and Kaley 2003e). Acute inhalation exposure to high concentrations (over 2 ppm) of phosphine can lead to coughing, severe lung irritation, tightness in the chest, and potential delayed pulmonary edema. Neurological symptoms upon acute exposure include dizziness, restlessness, difficulty walking, lethargy, seizures, convulsions, and coma and can also include a component of agitated psychotic behavior – which is very similar to symptoms seen upon exposure to methamphetamine (HSDB 2001b). Other signs of acute toxicity include rapid and/or irregular heart rate, low blood pressure, shock, nausea, abdominal pain, vomiting, diarrhea, and cardiac arrest (ATSDR 2000b). These symptoms are generally seen within a few hours of exposure with the exception of delayed onset kidney and liver toxicity.

Chronic inhalation exposure to low concentrations (0.5 to 2 ppm) of phosphine can lead to anemia, bronchitis, gastrointestinal symptoms (nausea, vomiting, loss of appetite, abdominal pain, and diarrhea), neurological effects (tremors, double vision, impaired gait, headache, giddiness, and difficulty speaking), liver damage (including jaundice), renal failure, toothache(s), jaw swelling, deterioration of the jaw bones, and spontaneous bone fractures (HSDB 2001b). Similar to chronic sodium hydroxide exposure, long-term inhalation exposure to phosphine can lead to RADS and has also been reported to induce structural changes in the chromosomes of the peripheral blood cells (Salocks and Kaley 2003e).

Skin and eye contact are generally secondary to inhalation exposures; however, irritation, tearing, pain, swelling, and sensitivity to light (photophobia) can be seen upon eye contact with phosphine gas (HSDB 2001b). Ingestion exposures are generally not expected unless certain waste materials from methamphetamine production are swallowed, which may result in liberation of phosphine gas within the stomach.

Methamphetamine is the desired end product of the cooking process and generally comes in a "free base" (methamphetamine base) or "hydrochloride salt" (methamphetamine hydrochloride) formulation. The initial product free base is yellow to brown liquid at room temperature and soluble in organic solvents at alkaline pHs; the salt is produced by bubbling hydrogen chloride through this liquid free base (Salocks and Kaley 2003f). The final product is a crystalline powder that can be clear to white to yellow dependent on purity. Oddly enough, methamphetamine is both a Schedule C controlled substance and a pharmaceutical agent, used as a nasal decongestant and to treat obesity and attention deficit disorder with hyperactivity (Salocks and Kaley 2003f).

Meth salt can be inhaled (smoked or snorted), ingested, or injected; the free base can also be injected (Wilburn 2003). Smoking the salt produces the most rapid onset of effects, but biological response is similar via all routes of exposure once absorbed. A number of factors determine biological effects of a given dose, including amount of exposure, age, route of exposure, and repeated exposures. Generally, injected/smoked meth produces an instantaneous high and accompanying "rush (or feeling of euphoria), snorting meth produces a high within 5 minutes, and ingested meth produces a high within 20 minutes (Vandeveld 2004).

Acute effects include blurred vision, loss of appetite, weight loss, lightheadedness, increased sweating, urticaria (intense itching of skin), ulcers of the lips and tongue, impotence, changes in libido, chest pain, and unpleasant taste nervousness, hyper-excitability, hyperactivity, irritability, assaultiveness, compulsive or repetitive behavior, euphoria, insomnia, tremor, restlessness, headache, drowsiness, fatigue, exacerbation of motor and phonic tics, and Tourette's syndrome (uncontrolled movement of the head, neck, arms, and legs) (PDR 2002).

Chronic exposure to methamphetamine hydrochloride may cause the following: severe dermatoses, insomnia, irritability, hyperactivity, personality changes, weight loss, poor concentration, grinding of the teeth, ulcers of the lips and tongue, anxiety, fear, compulsive/repetitive behavior, and possible self-injury (PDR 2002). Prolonged use of high doses of methamphetamine hydrochloride may result in a psychotic syndrome resembling schizophrenia, characterized by anxiety, fear, paranoid delusions, and visual, tactile and auditory hallucinations, and brief periods of delirium and disorientation. Prolonged use results in tolerance and psychological and physical dependence where withdrawal can occur from abrupt cessation of these high doses and result in mental depression, fatigue, vomiting, and nausea (MDL 2001).

High level exposures to methamphetamine may also cause cerebral infarction (localized oxygen deprivation, resulting in death of brain tissue and neurological deficit), hemorrhage (bleeding) and may ultimately result in collapse, shock, systemic acidosis (accumulation of acid in the body), coma, and convulsions (MDL 2001).

Appendix D – Overview of "Controlled Cook" Research using the Red Phosphorus Production Method (Martyny et al., 2004)

Clandestine drug laboratories are associated with both acute and long-term health hazards for not only those producing illicit substances but for those who dwell near these secret facilities. There are more specific health threats associated with the "Red Phosphorus" (Red P) production method outlined in this report, including not only the actual ingredients and end product but intermediary chemical and by-products as well. The vast majority of the more severe health threats exist during the active production of methamphetamine (or "cooking") with mainly dermal residual risk remaining once the lab is interrupted and dismantled. However, when cooking is performed in an area with greater population density (such as a hotel, motel, or apartment building), these more severe health threats are more likely to be seen among the innocents surrounding the lab.

Martyny et al (2004) reported that iodine compounds, phosphine, hydrogen chloride, and methamphetamine are the major chemicals of concern for the Red P method. Their study performed some "controlled cooks" using the Red P method and showed some unexpected results. This study reported the presence of hydrofluoric acid, hydrochloric acid, hydrobromic acid, phosphoric acid, nitric acid, and sulfuric acid following a Red P controlled cook performed in a Colorado criminology laboratory. Levels of hydrochloric acid exceeding the "ceiling" short-term exposure level (3 mg/m^3, see Table 1 below) were found during the cooking phase and levels slightly below the ceiling value during the "salting out" phase (when liquid free base methamphetamine is converted to solid meth salt). In fact, levels of hydrochloric acid (16.9 mg/m^3) were more than 5 times the ceiling value, indicating potential significant exposure during the active cooking phase.

Phosphine sampling during this controlled cook also exceeded short-term exposure standards; however, there was some uncertainty related to this data and future data from controlled cooks should be sought with regard to potential phosphine exposures. The maximum air concentration seen (0.49 mg/m^3) during controlled manufacture was roughly equal to the Acute Exposure Guideline Level 2 (AEGL-2) for a four-hour phosphine exposure (0.50 mg/m^3). The AEGL-2 is the "airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape" (See the Environmental Protection Agecny AEGL web site - http://www.epa.gov/oppt/aegl/define.htm). It is possible that anyone exposed to phosphine at 0.5 mg/m^3 for four hours could develop serious or irreversible adverse health effects, such as reactive airway dysfunction syndrome (RADS) or spontaneous bone fractures.

Airborne levels of iodine during the controlled cook also exceeded short-term exposure limits, including one sample (37 mg/m^3) that exceeded the Immediately Dangerous to Life and Health (IDLH) value of 2 ppm. Acute exposure of this magnitude can be expected to have significant neurological and cardiovascular effects. It could also be assumed that possibly dangerous levels of hydriodic acid would be associated with high concentrations of airborne iodine. It is unclear from the materials removed from the Harrison lab exactly how red phosphorus, tincture of iodine and possibly hydrogen peroxide were combined to effect the reduction of ephedrine to methamphetamine. One possibility is that red phosphorus and the iodine tincture were combined to form hydriodic acid, which breaks down in the presence of red phosphorus to form iodine and hydrogen (which is the real reducing agent here). Any non-reacted red phosphorus and iodine can react to form phosphorus iodide (PI_3), which further reacts with water to form phosphorus acid and more hydriodic acid in a self-perpetuating fashion (Uncle Fester 1999).

Table 1 lists out acute emergency exposure standards for the major chemical threats posed by the Red P method, *during active cooking*: iodine and the related compound hydroiodic acid, hydrochloric acid, and phosphine. The Martyny et al. (2004) study showed that the Red P method is capable of generating:

- Airborne hydrochloric acid concentrations above levels of acute concern (specifically, higher than the Occupational Safety & Health Administration [OSHA] "permissible exposure level" [PEL] ceiling value)
- Airborne phosphine concentrations roughly equivalent to levels of acute concern (specifically, roughly equivalent to the 2nd tier "acute exposure guideline level")
- Airborne iodine concentrations slightly above levels of acute concern (specifically, one sample exceeded the "Immediately Dangerous to Life and Health" value)
- Airborne hydrogen iodide was not tested for by Martyny et al. (2004); however, it could be found in association with airborne iodine. In addition, hydrogen iodide has corrosive effects similar to exposure to hydrogen chloride (hydrochloric acid) when it comes into contact with moist tissues (such as eyes or mucous membranes)

Table D-1. Some major Red P method contaminants and their associated exposure levels.

Compound	IDLH	OSHA PEL	ACGIH TLV	NIOSH REL	AEGL-1	AEGL-2
Iodine	2 ppm	Ceiling – 1 mg/m3 (0.1 ppm)	Ceiling – 1 mg/m3 (0.1 ppm)	Ceiling – 1 mg/m3 (0.1 ppm)	N/A	N/A
Hydrogen iodide, hydriodic acid					1 ppm proposed (10 min to 8-hr)	11 ppm proposed 8-hr
Phosphine	50 ppm	0.4 mg/m3 (0.3 ppm)	0.4 mg/m3 (0.3 ppm)	0.4 mg/m3 (0.3 ppm)	NR	0.25 8-hr interim; 0.5 for 4-hr exposures
Hydrogen chloride, hydrochloric acid	50 ppm	Ceiling – 7 mg/m3 (5 ppm)	STEL ceiling – 3 mg/m3	Ceiling – 7 mg/m3 (5 ppm)	1.8 ppm interim (10 min to 8-hr)	11 ppm interim 8-hr

ACGIH = American Conference of Governmental Industrial Hygienists; AEGL = Acute Exposure Guideline Level; IDLH = Immediately Dangerous to Life and Health; N/A = not applicable; NR = not recommended; NIOSH = National Institute for Occupational Safety & Health; OSHA = Occupational Safety & Health Administration; PEL = permissible exposure level; REL = recommended exposure level; TLV = threshold limit value

Martyny et al (2004) also took wipe samples both prior to and after the controlled cook for amphetamine, methamphetamine, ephedrine, and pseudoephedrine. One "post-cook" sample contained all four substances at levels equal to or greater than current remediation standards (which range from 0.1 to 5 micrograms (µg) per square foot, with most states adopting 0.5) with a maximum value of 16 µg/100cm^2 for methamphetamine. Wipe samples taken from equipment used during the cook registered 5200 µg (on a beaker used during manufacture) and 7900 µg (on a stirring rod), which were 2 orders of magnitude greater than the wipe sample results obtained by wiping the upper portion of the laboratory hood.

It should be noted that all samples taken in the Colorado criminology lab were done in a safe and protective environment. Protective equipment such as a chemical hood (which draws contaminants into it via air flow) would not be expected in a home production setting and, therefore, some of the expected exposure levels in these settings may be much higher than what is reported here.

Martyny et al (2004) also reported the results of sampling performed at sixteen (16) different clandestine meth labs, although none of them were active at time of sampling. Generally, the presence of inorganic acids (like hydrochloric acid) were not expected unless there was active cooking taking place; however, hydrochloric acid was found at very low levels at two of the sampled labs (both of them mobile homes). Likewise, phosphine gas would also not be expected to be present unless an active cook was occurring, as it is a fairly reactive gas. One sampled lab did report a fairly high hit for phosphine (0.36 µg/m^3); however, the problems with the air sampling for phosphine within this study have been mentioned prior. It is difficult to draw anything but tenuous conclusions from the phosphine data; however, the authors speculate that it is "possible that somehow an accumulation of phosphine was present" (Martyny et al 2004). Although many samples labs were reported to have obvious iodine staining within, air samples taken at these labs were all below the short-term exposure limits for iodine reported in Table 1. Hydriodic acid samples were not taken and may be useful for any future planned meth lab sampling, controlled or otherwise.

Additionally, almost 100 wipe samples for methamphetamine were taken from 14 meth labs. These samples were analyzed for amphetamine, methamphetamine, ephedrine, and pseudoephedrine, of which 83 samples were positive – ranging from 0.4 µg per sample to 16,000 µg per sample (this higher number was taken in a hotel room where an explosion had occurred during manufacturing). Sixteen (16) of these samples were positive for all four analytes tested for and the vast majority of these 16 samples were taken from flat hard surfaces or from vents/grills handling air flow. Ten of the fourteen meth labs tested had positive hits for **every** sample taken, with an overall mean of 499 µg per sample across the almost 100 samples. From this data, it can be reasonably assumed that every operational clandestine meth lab will have widespread contamination of amphetamine, methamphetamine, ephedrine, or pseudoephedrine at fairly high concentrations. Furthermore, due to the fact that many high hits were found in refrigerators, microwave ovens, and other kitchen appliances, there is reasonable potential for secondary exposures through consumption of contaminated food or dermal contact with a kitchen appliance.

One final test of note was performed during the sampling efforts of Martyny et al (2004). A stuffed teddy-bear was placed about 12 inches from the location of the controlled cook and later tested for surface pH and methamphetamine content after a cook was conducted. Surface pH on the stuffed bear indicated a pH of 1, while methamphetamine levels were measured at 3100 and 2100 µg per 100 square centimeters for the outer and inner fur layers that were tested. The results of this test have grave implications for children who come into contact with absorbent items that were sited near an active meth cook, having both corrosive dermal effects from the extremely low pH and dermal absorption effects from the high level of meth on the surface of absorbent items, like the stuffed bear.

Appendix E – Health Effects Questionnaire used for the Harrison Meth Lab

Central Michigan District Health Department
Potential Chemical Exposure Questionnaire

(Please read to the person being interviewed.)
The Central Michigan District Health Department is investigating a potential exposure to chemicals that might have been associated with the production of methamphetamine. The answers to these questions and your identity are held in strict confidentially. You may have a copy of this questionnaire. The information obtained will be used to help scientists determine a safe level of exposure to certain chemicals.

Today's Date

Name or Unique Identifier

Date of Birth and Age and Sex

When did you first move into the apartment located at (address)?

What was the apartment number you lived in that is located at (address)?

If you moved from the apartment at (address) when did you move?

Health History

Do you see a doctor on a regular basis for any health problems? Please list any conditions for which you see a doctor on a regular basis.

Have you ever been hospitalized? When were you hospitalized and why were you hospitalized?

Are you currently taking any medications? If so, what medication are you taking?

While you were living in the apartment at (address).

Did you ever notice any unusual activity in any of your neighboring apartments? If so please describe the unusual activity. (Were there people visiting your neighbors all day and all night?)

If there was unusual activity in any of your neighboring apartments, how long did this continue?

Is there carpeting in the room next to your neighbor's apartment?

While you were living in the apartment at (address) did you ever notice any strange odors? Can you describe the odors?

If you noticed strange odors while living in the apartment at (address), how long did you notice them? Were the strange odors present for days or weeks or months?

If you noticed strange odors while living in the apartment at (address), could you tell where the odors were coming from?

When you were living in the apartment at (address), did you or anyone living with you experience any ill health?

If you or someone that was living with you experienced health problems while living at (address), what were those symptoms?

Did the health problems you or someone you lived with at (address) occur when you smelled the strange odor?

If you or someone that was living with you experienced health problems while living at (address), did you see a doctor or go to a clinic? If so, what did the doctor say was the reason or diagnosis for which you were seen?

If you or someone you were living with in the apartment at (address) was sick, have those symptoms or condition improve or go away?

Additional Comments

Do you have any additional comments you would like to make about the time you live in the apartment at (address)?

Name of interviewer:

Appendix F – MDCH Recommendations for Remediation at the Harrison Red P Meth Lab Submitted to Property Owner in March 2004

In response to a request from the Central Michigan District Health Department (CMDHD) for remediation guidelines following the dismantling of a methamphetamine laboratory ("meth lab") in Harrison, MI, in late January 2004, I've prepared the following memorandum and technical support document. The technical support document is primarily intended for the CMDHD but is also included here for your general information. Within these suggestions, the 'cooking area' refers to the bedroom where the manufacturing materials were discovered. The 'secondary contamination area' refers to the remainder of the apartment.

Actions suggested for the cooking area:

- Remove all absorbent material from the room, to include carpeting, drapes, wallpaper, clothing, bedding, or other personal effects. This material should be considered hazardous waste. Removal and proper disposal of such waste should be carried out by an appropriately certified and skilled contractor.
- All surfaces with visible contamination need to be removed and replaced, to include ceiling material, wall material and molding. All removed material should be considered hazardous waste. Removal and proper disposal of such waste should be carried out by an appropriately certified and skilled contractor.
- The air vents within the cooking area should be intensively cleaned with a water-detergent solution and than covered with a substance that can encapsulate any remaining contamination (such as varnish, oil-based paint, or similar sealant).

Actions suggested for the secondary contamination area:

- Remove all absorbent material from the room, to include carpeting, drapes, wallpaper, clothing, bedding, or other personal effects. This material should be considered hazardous waste. Removal and proper disposal of such waste should be carried out by an appropriately certified and skilled contractor.
- All non-hard surfaces in the remainder of the apartment should be intensively cleaned with a water-detergent solution and then covered with a substance that can encapsulate any remaining contamination (such as varnish, oil-based paint, or similar sealant). Non-hard surfaces as defined here include drywall, other wall and ceiling materials, cabinetry, doors, and molding. Similarly, all hard surfaces (like counter top, tile counter and/or flooring, linoleum, etc.) should also be cleaned with a water-detergent solution. Any hard items with visible contamination remaining after cleaning in the apartment hallway or kitchen should probably be removed and properly disposed of, as these areas are likely areas of contaminant migration.
- All air filters within the building ventilation system should be replaced and properly disposed of. All ventilation registers in the remainder of the apartment should be removed and intensively cleaned with a water-detergent solution and than covered with a substance that can encapsulate any remaining contamination (such as varnish, oil-based paint, or similar sealant).

It is imperative to treat all material removed from the apartment as hazardous solid waste to minimize any possible health effects from exposure to residual contamination from the meth lab. Appropriately skilled and educated contractors should be used to perform this work and proper personal protective equipment should be used. Syringes or other blood-stained material should be treated as a biohazard and handled appropriately. Please consult the Central Michigan District Health Department for guidelines on proper disposal of such items.

Comments or concerns over these suggested remediation guidelines can be directed to Erik R. Janus, Toxicologist, Michigan Department of Community Health at toll-free phone number (800) MI TOXIC or email address januse@michigan.gov.

Sincerely,

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