Evaluation of Exposure to the Chemosterilant Bisazir Among Biological Technicians – Michigan

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Health Hazard Evaluation Report
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The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

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Acknowledgments

Abbreviations

µg	microgram
µg/m^3	micrograms per cubic meter
µg/L	micrograms per liter
ACGIH®	American Conference of Governmental Industrial Hygienists
cm	centimeter
cm^2	square centimeter
CFR	Code of Federal Regulations
DNA	Deoxyribonucleic acid
GA	General area
HHE	Health hazard evaluation
IgG	Immunoglobulin G
LOD	Limit of detection
LOQ	Limit of quantitation
MDC	Minimum detectable concentration
mL	Milliliter
MSDS	Material safety data sheet
NAICS	North American Industry Classification System
ND	Not detected
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OOHS	Office of Occupational Health and Safety
OSHA	Occupational Safety and Health Administration
PAPR	Powered air purifying respirator
PBZ	Personal breathing zone
PEL	Permissible exposure limit
PPE	Personal protective equipment
REL	Recommended exposure limit
STEL	Short term exposure limit
TLV®	Threshold limit value
TMF	3-trifluoromethyl-4-nitrophenol
TWA	Time-weighted average
WEEL	Workplace environmental exposure level

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation at a biological station in Michigan. A federal government agency concerned about possible health effects to employees handling the chemosterilant bisazir submitted the request. Bisazir is used to control sea lampreys, an aquatic parasite of fish in the Great Lakes.

What NIOSH Did

- We evaluated the biological station in May 2010.
- We watched employees work and spoke with them about their work practices and health concerns.
- We tested air, water, surfaces, and work gloves for bisazir.
- We tested urine samples from three employees for bisazir.

What NIOSH Found

- We found no bisazir in the air, water, surface, or work glove samples.
- We found no bisazir in the urine samples.
- Employees wore the correct personal protective equipment (PPE) and followed procedures.

What Managers Can Do

- Continue to talk to employees about the hazards of bisazir and teach them safe handling practices.
- Determine if PPE can be downgraded in future sterilization seasons.

What Employees Can Do

- Attend training about handling bisazir safely.
- Follow recommended work practices and PPE procedures.

Summary

In October 2009, NIOSH received an HHE request from a federal government agency concerning employees' potential exposure to the chemosterilant bisazir at a biological station in Michigan. Bisazir is used to sterilize male sea lampreys, an invasive aquatic parasite of the Great Lakes.

NIOSH evaluated potential exposure to the chemosterilant bisazir among employees of a biological station. We detected no bisazir in environmental or urine samples. Engineering and administrative measures and PPE effectively protected employees.

We evaluated the biological station on May 19–20, 2010. We walked through the facility and observed work processes, practices, and conditions. We spoke with employees about health and workplace concerns related to bisazir and collected samples for bisazir from air, water, surfaces, gloves, and urine.

We detected no bisazir in general area air samples (MDC ≤ 0.8 μg/m^3), PBZ air samples (MDC ≤ 2.0 μg/m^3), or cotton glove samples (LOD = 10 μg/sample). No bisazir was detected in the employees' urine samples. No bisazir was detected in bulk water samples taken from tanks that housed bisazir-treated sea lampreys (LOD = 0.4 μg/L). We found that employees were aware of the potential risks from exposure to bisazir and that they followed administrative procedures and PPE recommendations.

Because we sampled over just 2 workdays and during only one sea lamprey spawning season, additional air and surface sampling during the upcoming 2011 season would be useful to confirm these results. If no bisazir is detected in these additional samples and the good work practices and engineering controls we observed continue, management could consider downgrading the level of PPE required for working in the injection and tank rooms. The agency had previously used semen analysis to identify possible adverse reproductive effects, but discontinued this program in 2009 as semen analysis is not an appropriate measure of the effects of bisazir exposure.

Keywords: NAICS 924120 (Administration of Conservation Programs), sea lamprey, bisazir, alkylating agent, chemosterilant

Introduction

In October 2009, NIOSH received an HHE request from a federal government agency concerning potential employee exposure to the chemosterilant bisazir that is used at a biological station in Michigan. Bisazir is used to sterilize male sea lampreys, an invasive aquatic parasite of the Great Lakes.

Sea Lampreys

The sea lamprey (*Petromyzon marinus*, Figure 1) is an eel-like aquatic animal with a suction-cup-like jawless mouth. Adult sea lampreys measure 12 to 48 inches in length. They parasitize fish by adhering to them with their mouth, filing a hole with their tongue, and suctioning blood and body fluids. Sea lampreys began invading the Great Lakes in the mid-1800s, entering from the Atlantic Ocean through the Erie Canal, reaching Lake Superior in the 1940s and causing great damage to the fish population [Christie and Goddard 2003]. In 1955, Canada and the United States created the Great Lakes Fisheries Commission to protect the fisheries of the Great Lakes. The U.S. Department of the Interior Fish and Wildlife Service is the U.S. agency represented on the Commission.

Figure 1. Photograph of two male sea lampreys that escaped from the transfer basket, lying by the side of the tank truck. The arrow indicates the missing dorsal fin, which was cut off to mark the sea lamprey as sterilized.

Control of sea lampreys has been achieved primarily through application of the selective larvicide TMF in tributaries of the Great Lakes, migratory barriers, and trapping. A secondary technique of releasing sterile male sea lampreys to compete with fertile ones was implemented in 1991. This sterile male release technique relies on trapping large numbers of sea lampreys in tributary rivers as they begin their spawning run in the spring [Twohey et al. 2003].

Sterilization Process

The sea lamprey sterilization facility operates during the sea lamprey spawning season, which extends from the end of April to early July. This custom-built sterilization facility houses the injection room (Figure 2), a large tank room with holding tanks and a water pump system, a decontamination room, bathrooms with lockers and showers, an office, and a storage room with workshop. The sterilization room has a general area ventilation system and a fume hood equipped with activated carbon and high efficiency filters. Both systems exhaust 100% of the ventilated air outside the building. During the spawning season the sterilization facility operates daily. At the end of the season the facility is decontaminated and shut down for the remainder of the year.

Figure 2. Photograph of the injection room, with fume hood on the right, an employee operating the automated injection machine in the center, and bisazir storage refrigerator between them. Sea lampreys are held in the tank on the left before sterilization.

The number and trend of sea lampreys trapped over the spawning run gives managers an indication of how many sterilization sessions are needed. Up to 350 sea lampreys are sterilized in one session, with up to four sessions per day, for a total of 1,400 sea lampreys per day. On average 26,500 sea lampreys are sterilized per season, with a maximum of 43,184 in 2000 [Bergstedt and Twohey 2007].

Eight employees (all but one male) were working with bisazir at the time of our visit. These employees received an annual occupational health exam post season, including pulmonary function test, and because some job tasks exposed them to a wilderness environment, Lyme disease serology. In the past, male employees who worked with bisazir had an annual semen analysis to identify possible adverse reproductive effects. A review of the program in 2009 by the agency revealed that this was an inappropriate test to detect adverse effects from bisazir, and it was discontinued.

Employees entering the injection room and tank room areas were required to wear a 3M Breathe-Easy™ loose-fitting PAPR with cartridges protective against organic vapors, sulfur dioxide, chlorine, and hydrogen chloride. The PAPR was selected because of comfort and ease of use during long periods, and because it does not require fit testing. The site had a written respiratory protection program that included respirator medical clearance for new hires, continuing medical clearance evaluations, proper respirator maintenance and storage procedures, and cartridge selection in accordance with OSHA respiratory protection standards [CFR 1910.134].

To minimize skin contact with bisazir, the employees wore DuPont Tychem® SL (Saranex) coveralls and butyl rubber gloves and boots. The gloves and boots were sealed to the Saranex coveralls with tape. To sterilize sea lampreys, two employees suited up to enter the containment area. Following a schedule, they alternated during the day with two other employees. Employees worked 10 consecutive days in the sterilization facility, followed by 4 days off.

The sea lampreys were transported in trucks to the biological station where males and females were manually separated. Female sea lampreys were shipped off to become dissection specimens for biology classes. Male sea lampreys were placed into holding tanks and transported into the sterilization room. A technician placed an individual sea lamprey on a scale to determine the weight-dependent (100 mL per kilogram) dose of a 1% solution of bisazir (P, P-bis(1-aziridinyl)-N-methylphosphinothiotic amide) to inject.

The sea lamprey was then inserted by hand into the automated injection machine where the injection occurred in a closed, ventilated box (Figure 3). The injection machine then released the sea lamprey into a holding tank outside the sterilization room. Sea lampreys were then held in tanks for 48 hours to allow them to metabolize the bisazir.

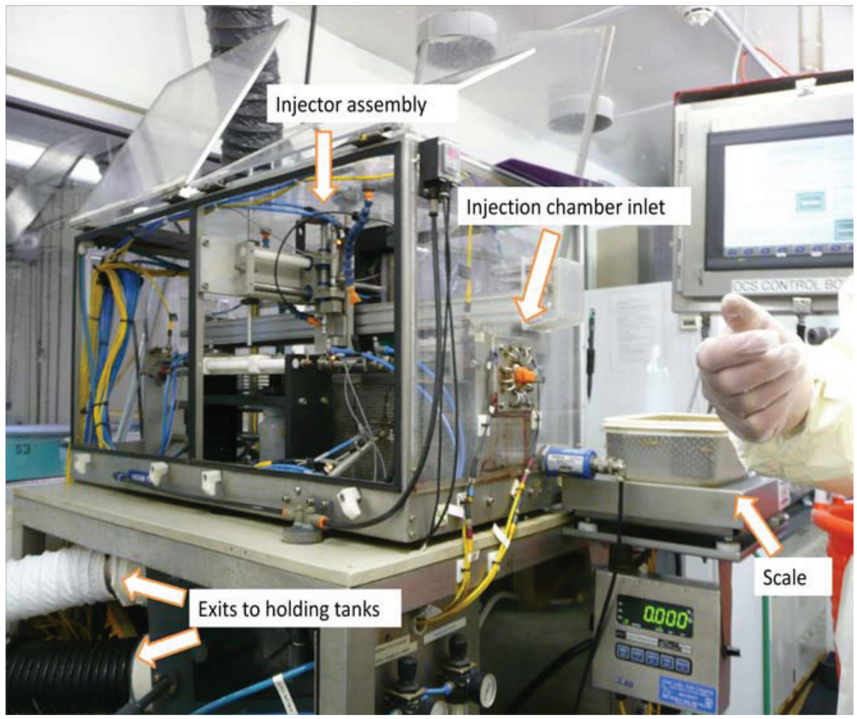

Figure 3. Photograph of the automated injection machine. Sea lampreys were weighed on the scale, then inserted tail first through the inlet. The machine pulled the sea lamprey in, injected it with the correct dose of bisazir, and released it into a holding tank. The machine was usually closed during operation but is open in the photograph for mechanical troubleshooting.

The bisazir solution was prepared in a Hamilton SafeAir® fume hood in the sterilization room. Pure bisazir powder was received from the manufacturer in premeasured packets and stored cold. To make a 1% solution, the bisazir was removed from refrigerated storage, placed inside the fume hood, and then opened and weighed. The bisazir powder was emptied into a flask containing the premeasured saline and a magnetic stirrer. The flask was then placed on the magnetic stirrer platform and mixed for at least 2 hours to ensure complete solution of the bisazir powder. While preparing bisazir solution within the fume hood, employees wore an additional clean pair of unlined nitrile gloves that were stored and kept inside the fume hood to prevent bisazir powder contamination. The bisazir solution was then manually transported to the automated injection machine and loaded into a closed delivery system. Decontamination was accomplished by using muriatic acid (pH = 2) to neutralize the bisazir.

After 48 hours in holding tanks, employees marked the sterilized male sea lampreys by removing part of their dorsal fin before release into the St. Mary's river. Once released, sterile male sea lampreys resume their spawning run, swimming back to the rivers to find and mate with females. Although sterile male sea lampreys produce milt and fertilize the eggs of the females, the resulting embryos are not viable.

Water from Lake Huron supplied the sea lamprey holding tanks. The water was circulated back to the lake after passing through a carbon filtration system to prevent contaminating the lake with bisazir. The outflow water was tested weekly for bisazir at a laboratory across the street.

In 2002, prompted by the use of bisazir and the larvicides TMF and Bayluscide, the agency evaluated the biological station's operation and drafted employee medical standards and a medical examination protocol. The agency re-evaluated these procedures in 2009, after an employee had been medically restricted from working with bisazir because of abnormal semen analysis results. The 2009 evaluation led to this HHE request that asked (1) what is the potential for exposure to bisazir at the facility?, (2) are there adverse health effects related to exposure to bisazir?, (3) are the proper tests being used to monitor exposure?, and (4) is there a better way to monitor potential exposure to bisazir?

Prior to our site visit we talked with the requestors by phone to review previous evaluations and to request an MSDS for bisazir and a copy of the medical standards. We also requested copies of medical records from one employee with abnormal semen analysis. We reviewed the 2002 and 2009 evaluations of the facility's procedures by the agency, the medical standards and medical examination protocol, and the OSHA Form 300 Log of Work-related Injuries and Illnesses for the facility for the years 2007–2009.

During our site visit on May 19–20, 2010, we held opening and closing meetings with local managers and employee representatives. Three of the four employees who were scheduled to work in the injection room signed consent forms and agreed to provide urine to be tested for bisazir. We spoke with the employees present at the time about their work practices when handling bisazir and about any health concerns.

We collected PBZ and GA air, wipe, and cotton glove liner samples to test for bisazir. The PBZ air samples were taken on employees entering into either the injection room or the tank room. Employees typically worked 3 to 4 hours in the injection or the tank room. GA air samples were placed in the decontamination area, sterilization room, and tank room. PBZ and GA air samples were taken using AirChek 2000 air sampling pumps calibrated to 1 liter per minute. PBZ samples were taken for the time spent in either the injection room or the tank room (186 to 301 minutes). GA samples were taken for the working day (429 to 528 minutes). Air samples were collected on OSHA Versatile Sampler-2 sorbent tubes and stored on ice immediately after sampling was concluded. The OSHA Versatile Sampler-2 tubes were analyzed for bisazir by gas chromatography equipped with flame photometric detection with an LOD of 0.4 µg of bisazir per sample and an LOQ of 1.4 µg of bisazir per sample. The MDC of bisazir in PBZ samples was 2 $\mu g/m^3$ based on a 267-liter air sample. The MDC of bisazir in GA samples was 0.8 $\mu g/m^3$ based on a 474-liter air sample. The sampling method was NIOSH Method 5600 for organophosphorus pesticides modified for analysis of bisazir [NIOSH 2011]. The front and back sections of the tubes were transferred to separate 4-mL vials, and 2 mL of a 10% acetone and 90% toluene solution was added. The quartz fiber filter was desorbed together with the front sorbent section. The vials were placed on a mechanical shaker for 60 minutes and subsequently transferred to amber autosampler vials for analysis by gas chromatography equipped with flame photometric detection.

Surface wipe samples were taken using Alpha Texwipe® wipes moistened with 100% isopropanol. A 10 cm × 10 cm square template was used to determine a 100 cm^2 sampling area. The surface wipe samples were collected in the injection room, tank room, decontamination room, men's and women's restrooms, office area, and on an outdoor storage tank that held sterilized sea lampreys awaiting release. The sample media was analyzed for bisazir by gas chromatography equipped with flame photometric detection with an LOD of 2 µg of bisazir per sample and an LOQ of 8.0 µg of bisazir per sample. The sampling method is NIOSH Method 5600 for organophosphorus pesticides modified for analysis of bisazir [NIOSH 2011]. The wipe samples were placed in individual desorption vials. The wipes were chemically desorbed by adding 15 mL of 10% acetone/90% toluene solution. The vials were placed in a mechanical shaker for 60 minutes. After shaking, the samples were transferred to amber autosampler vials for analysis by gas chromatography equipped with flame photometric detection.

To evaluate potential dermal exposure we asked employees to wear 100% cotton gloves (Lab Safety Supply, Janesville, Wisconsin) under their Tyvek® gloves. The cotton gloves were collected at the end of the shift by NIOSH investigators wearing sterile gloves and analyzed for bisazir to evaluate potential dermal exposure from permeation or leakage through the gloves or contamination when the employee donned or doffed them. Each pair of cotton gloves was analyzed for bisazir by gas chromatography equipped with flame photometric detection. The LOD was 10 µg of bisazir per sample, and the LOQ was 35 µg of bisazir per sample. The sampling method was NIOSH Method 5600 for organophosphorus pesticides modified for analysis of bisazir [NIOSH 2011]. The individual gloves were placed into 100-mL wide mouth jars. The jars were chemically desorbed by adding 15 mL of 10% acetone/90% toluene solution. The jars were placed in a mechanical shaker for 60 minutes. After shaking, an aliquot of the sample was transferred to amber autosampler vials for analysis by gas chromatography equipped with flame photometric detection.

We collected bulk water samples from the retention tanks by manually lowering a glass jar into the tank while wearing protective gloves. The jar was rinsed three times before collecting the sample. Each bulk sample was analyzed for bisazir by gas chromatography equipped with flame photometric detection. The LOD was 0.4µg/L of bisazir per sample, and the LOQ was 1.4µg/L of bisazir per sample. The sampling method was Environmental Protection Agency Method 8141A for organophosphorus compounds modified for analysis of bisazir [Environmental Protection Agency 1992]. The bisazir was extracted from the water using a separatory funnel technique. The water sample was extracted three separate times with 60 mL of methylene chloride. The three extractions were combined. The extract was evaporated down to approximately 1 mL under nitrogen using a Turbovap concentrator. The methylene chloride was solvent exchanged with n-hexane at this point. The extract was concentrated down to a final volume of 1 mL using the Turbovap concentrator. The extracts were analyzed by gas chromatography equipped with flame photometric detection.

Urine samples were collected by employees and submitted for analysis. Sample aliquots of 20 mL were extracted and then 2.0 mL of methylene chloride was added to each sample. The sample was shaken for 10 minutes and then allowed to stand for at least one hour. The methylene chloride extract was then dried with sodium sulfate prior to the addition of internal standards. Analysis was completed by gas chromatography/mass spectrometry. The LOD was 25 µg/L of bisazir per sample, and the LOQ was 83 µg/L of bisazir per sample.

No OELs exist for bisazir. The scientific literature contains no reports of human health effects from exposure to bisazir.

Results

We detected no bisazir in any of the samples we took. No bisazir was detected (LOD of 25 µg of bisazir per liter) in the urine of the three employees. As shown in Table 1, airborne bisazir was not detected; concentrations were below the MDC of 0.8 µg/m^3 (for a 474-liter GA air sample) and 1.5 µg/m^3 (for a 267-liter PBZ air sample). No bisazir was detected (LOD = 2 µg of bisazir per 100 cm^2) on any of the surface wipe samples (Table 2). As shown in Table 3, no bisazir was detected (LOD =10 µg of bisazir per sample) on any of the cotton gloves worn under the protective gloves by employees who performed various activities, including mixing bisazir in the sterilization chamber, weighing and injecting bisazir, and transporting sea lampreys in the tank room.

We observed employees using proper work practices when working with bisazir. All observed employees were wearing the proper PPE, utilizing engineering controls, and thoroughly decontaminating their equipment with the muriatic acid solution. We observed one preparation of bisazir solution during which employees adhered strictly to the standard operating procedures posted near the fume hood.

Table 1. Bisazir concentrations in air samples collected on May 19–20, 2010

Sample Location	Sample Description	Time (minutes)	Conc.
PERSONAL BREATHING ZONE			
Injection room	Weighing and loading sea lampreys into injection machine	196	ND*
Injection room	Weighing and loading sea lampreys into injection machine. Also mixed bisazir into solution.	186	ND*
Injection room	Weighing and loading sea lampreys into injection machine	354	ND*
Tank room	Transferring sea lampreys, emptying holding tank to outside tank	297	ND*
Tank room	Transferring sea lampreys, emptying holding tank to outside tank	301	ND*
Tank room	Transferring sea lampreys	270	ND*
GENERAL AREA			
Injection room	Table across from fume hood near injection machine	471	ND†
Injection room	Table across from fume hood near injection machine	474	ND†
Tank room	On top of holding tank P1	473	ND†
Tank room	On top of holding tank P1	475	ND†
Tank room	Far corner near transfer tank from outside	469	ND†
Tank room	Far corner near transfer tank from outside	469	ND†
Decontamination room	On window sill near hallway to injection room	528	ND†
Decontamination room	On window sill near hallway to injection room	429	ND†

*The MDC was 2.0 μg/m^{3}for a 267-liter air sample (average PBZ sample volume).
†The MDC was 0.8 μg/m^3 for a 474-liter air sample (average GA sample volume).

Our conversations with employees indicate that they were aware of the potential risks from exposure to bisazir (i.e., it is an alkylating agent that can damage tissues and have mutagenic and teratogenic effects). Employees did not report any recognized breakdowns in the engineering controls (automated injector or general ventilation) or PPE that could have led to accidental exposure to bisazir.

Table 2. Bisazir surface sample results from May 19–20, 2010

Description	Result (µg/100 cm²)
Door handle exiting tank room into decontamination area†	ND*
Side of tank P2 in tank room	ND*
Table of injection room	ND*
Substrate of fume hood before mixing bisazir	ND*
Substrate of fume hood after mixing bisazir	ND*
Door handle from restroom to decontamination area†	ND*
Men's restroom floor before entering decontamination area	ND*
Decontamination area floor before entering men's restroom	ND*
Women's restroom floor before entering decontamination area	ND*
Hallway floor outside injector room	ND*
Side of tank 1 outside holding tank	ND*
Office floor next to computer	ND*
Women's restroom floor	ND*

*ND = not detected (below the LOD of 2.0 µg per sample)
†The 100 cm^2 template could not be used on door handles. Sample was taken from the surface of the door handle.

Table 3. Bisazir sample results for cotton glove samples* from May 19–20, 2010

Sample Location	Sample Description	Result (µg/sample)
Injection room	Weighing and injecting sea lampreys	ND†
Injection room	Mixing bisazir solution	ND†
Injection room	Weighing and injecting sea lampreys	ND†
Tank room	Transferring sea lampreys, emptying holding tank to outside tank	ND†
Tank room	Transferring sea lampreys, emptying holding tank to outside tank	ND†
Tank room	Transferring sea lampreys	ND†
Tank room	Transferring sea lampreys	ND†

*Each sample consisted of a pair of cotton gloves worn by employees under their outer gloves.
†ND = not detected (below the LOD of 10 µg of bisazir per sample)

Results (continued)

Review of semen analysis reports from one employee showed variability in sperm count from normal to decreased and atypical sperm morphology. Most samples were from the winter months, beyond the time frame where spermatogenesis would have been affected from a springtime exposure to a sterilant. The other employees had no reports of semen analysis abnormalities or of infertility or adverse reproductive outcomes.

The OSHA Logs for the years 2007–2009 contained reports of 22 injuries and one illness, a tick bite believed to have caused Lyme disease in 2009. These injuries and illness were not sustained at the sterilization facility, but rather during field work. No unusual injury types or patterns were reported.

Discussion

Bisazir is an alkylating agent in the nitrogen mustard class developed in the 1960s for agricultural pest control applications. It was found to be an effective chemosterilant in sea lampreys in tests conducted in the 1970s [Hanson and Manion 1980].

Studies on sea lampreys show that bisazir-induced infertility results from DNA damage in the sperm cells, while the numbers, morphology, and motility of the sperm are unaffected. The damage consists of DNA adducts, and DNA-DNA and DNA-protein linkages [Ciereszko et al. 2005]. An experiment on mice showed that bisazir induced abnormal metaphases in spermatogonia and sperm head abnormalities [Devi and Reddy 1985]. These two findings suggest that semen analysis is not appropriate for detecting the type of damage induced by bisazir in men, assuming the effects are the same as for mice. Although bisazir has not been used in humans, similar nitrogen mustard compounds (e.g. cyclophosphamide and thiotepa) are used as chemotherapeutics for treating cancers. In mice, cyclophosphamide causes germ cell phase-specific DNA damage [Codrington et al. 2004]. Toxic clinical effects of cyclophosphamide and thiotepa include defective spermatogenesis and oogenesis. Adverse effects to a fetus may be caused by either male or female treated parent, and they may cause infertility in males and females [DrugPoints® System 2009a; DrugPoints® System 2009b].

Furthermore, the medical surveillance program for the biological station does not address reproductive issues in female employees, who are potentially equally at risk of adverse reproductive health effects from exposure to bisazir.

Employees are understandably concerned about potential adverse reproductive effects and should be informed about what they can do to minimize their risk of such effects. The Washington State Department of Labor and Industries' Safety and Health Assessment and Research for Prevention Program has prepared a comprehensive technical report titled "Workplace Hazards to Reproduction and Development: A Resource for Workers, Employers, Health Care Providers, and Health & Safety Personnel" [http://www.lni.wa.gov/Safety/Research/files/repro_dev.pdf]. The section on "How Workers Can Protect Themselves" (p. 55) can be adapted for the needs of the biological station.

Bisazir exposure pathways can potentially include inhalational (from powder and liquid forms) and dermal routes. The vapor pressure of bisazir is not available from the MSDS. Review of scientific literature estimates the vapor pressure of bisazir at 0.005 millimeters of mercury at 25°C, which indicates that bisazir is highly volatile [Carlson and Bailey1981]. However, the vapor pressure was estimated by comparing gas chromatography retention times to n-paraffins, which is not an ideal method for determining vapor pressure but is acceptable [Letcher and Naicker 2004]. Additional information that may also be used to better determine the volatility of bisazir such as Henry's constant (determined by both volatility and water solubility) was not available. Bisazir in powdered form can be an inhalational hazard. In a saline solution, bisazir should be considered volatile until proven otherwise [Streicher 2010]. Bisazir is water soluble as evidenced by the chemical structure and the chemical analysis of effluent water from the station. Bisazir in liquid form or water contaminated with bisazir should be considered a dermal hazard.

Our sampling results did not detect bisazir in the air or on work surfaces, and no bisazir was detected in the urine samples from three employees. However, because we collected air and surface samples over just 2 workdays during only one sea lamprey spawning season, additional sampling may be needed to confirm our findings. On the basis of observations of protective standard operating procedures, good work practices, adequate engineering controls, and negative bisazir sample results, the level of PPE may be downgraded in subsequent sterilization seasons.

Regarding the four questions in the HHE request, we found that (1) the potential for bisazir exposure was low, (2) no adverse health effects were attributable to bisazir exposure, (3) semen analysis was not the proper test to detect reproductive effects of bisazir, and (4) despite limitations in detection limits of chemical analysis, environmental and urine sampling for bisazir are better than semen analysis to monitor potential exposure to bisazir.

Current Lyme disease assays (i.e., enzyme immune assay-specific IgG antibodies to *Borrelia burgdorferi*) have poor specificity, are not useful

Discussion (continued)

in screening persons without objective manifestations of disease, and are costly [Wormser et al. 2006]. Testing for Lyme disease should be guided by the presence of symptoms and signs compatible with Lyme disease. Although the biological station is in an area where infected ticks are rare [ALDF 2011], employees should be educated about the signs and symptoms of Lyme disease because their field tasks expose them to ticks.

Conclusions

Employees were protected from bisazir exposure through engineering controls (ventilated automated injection device and fume hood), administrative practices, and PPE. Nevertheless, given the potential toxicity of bisazir, management should continue looking for effective chemosterilants that are less toxic to humans. Our sampling results did not detect bisazir in the air or on work surfaces, and no bisazir was detected in the urine samples from three employees. However, because we sampled over just 2 workdays and during only one sea lamprey spawning season, additional air and surface sampling during the upcoming season would be useful to confirm these results. If no bisazir is detected in these additional air and surface samples and the good work practices and engineering controls that we observed during this evaluation continue, the management of the biological station may want consider downgrading the level of PPE required for the employees working in the injection and tank rooms.

Recommendations

On the basis of our findings, we recommend the actions listed below to create a more healthful workplace. We encourage the facility to use an employee-employer health and safety committee or working group to discuss the recommendations in this report and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the facility. Our recommendations are based on the hierarchy of controls approach. This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and/or personal protective equipment may be needed.

Elimination and Substitution

Elimination or substitution of a toxic/hazardous process material is a highly effective means for reducing hazards. Incorporating this strategy into the design or development phase of a project, commonly referred to as "prevention through design," is most effective because it reduces the need for additional controls in the future.

- Investigate the use of other effective chemosterilants that are less toxic to humans.

Engineering Controls

Engineering controls reduce exposures to employees by removing the hazard from the process or placing a barrier between the hazard and the employee. Engineering controls are very effective at protecting employees without placing primary responsibility of implementation on the employee.

- Investigate ways to further isolate the bisazir supply to the automated injector such as extending the bisazir delivery system directly into the fume hood. This would allow for replacement of bisazir vials to occur within the fume hood and eliminate the potential for spills while transporting bisazir to the automated injection device.

Administrative Controls

Administrative controls are employer-dictated work practices and policies to reduce or prevent exposures to workplace hazards. The effectiveness of administrative changes in work practices for controlling workplace hazards is dependent on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that control policies and procedures are not circumvented in the name of convenience or production.

- Employees handling bisazir should be counseled regarding potential toxicity and reproductive hazards of bisazir, including overall risks of common adverse reproductive outcomes in the general population.
- Discontinue annual Lyme disease serology.
- Educate employees about signs and symptoms of Lyme disease.

Personal Protective Equipment

PPE is the least effective means for controlling employee exposures. Proper use of PPE requires a comprehensive program, and calls for a

Recommendations (continued)

high level of employee involvement and commitment to be effective. The use of PPE requires the choice of the appropriate equipment to reduce the hazard and the development of supporting programs such as training, change-out schedules, and medical assessment if needed. PPE should not be relied upon as the sole method for limiting employee exposures. Rather, PPE should be used until engineering and administrative controls can be demonstrated to be effective in limiting exposures to acceptable levels.

- Use the current PPE until exposures are re-evaluated: 3M Breathe-Easy Airstream loose-fitting PAPR with organic vapor/sulfur dioxide/hydrogen chloride/chlorine cartridges, DuPont Tychem SL coveralls, and butyl rubber gloves and boots.

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