Evaluation of Employee Exposures During Sea Lamprey Pesticide Application

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a health and safety manager at a government agency. Managers asked us to assess chemical exposures when employees manually applied pesticides into rivers to control sea lamprey larvae. The pesticides were 3-trifluoro-methyl-4-nitro-phenol (also called TFM) and Bayluscide™.

What We Did

- We observed employees while they applied pesticides.
- We looked at work practices and use of personal protective equipment.
- We interviewed employees about their work, use of personal protective equipment, work-related health symptoms, and health and safety concerns.
- We looked at health and safety records and documents.
- We measured TFM and Bayluscide on work surfaces, employees' work clothing, exposed skin, and glove liners worn under protective gloves.
- We measured carbon monoxide in a portable laboratory and a portable workstation. Both used propane-powered generators.

We evaluated employee exposures when applying pesticides to a river. We found pesticides on work surfaces, personal protective equipment, clothing, and employees' skin, and a high carbon monoxide peak concentration in a portable workstation. We recommend enclosing pesticide transfer and mixing equipment, developing personal protective equipment cleaning and storage procedures, providing employees with clean water, and rerouting generator exhaust.

What We Found

- We measured carbon monoxide in a portable workstation above the level that NIOSH says should not be exceeded at any time. One employee was working near the workstation when we took the measurement.
- We measured low concentrations of carbon monoxide in a portable laboratory.
- We found pesticides on employees' clothing and exposed skin. We did not find pesticides on liners worn under work gloves.
- Fewer than five employees reported skin irritation from TFM, skin rash, and poison ivy.
- Employees used personal protective equipment inconsistently and did not always have ways to clean it.
- Clean water for drinking and cleaning was not available at all field stations.

What the Employer Can Do

- Relocate the exhaust from power generators so employees are not exposed to carbon monoxide.
- Provide closed containers for handling of pesticides.
- Develop ways to clean and store personal protective equipment in the field.
- Provide drinking water for employees in the field.
- Encourage employees to report health or safety concerns to a supervisor.

What Employees Can Do

- Use required personal protective equipment.
- Clean personal protective equipment before storing or reusing.
- Wash hands and face with clean water and soap after handling pesticides.
- Change clothes when they become contaminated with pesticide and at the end of the work shift.
- Report all health and safety concerns to your supervisor. If you experience skin irritation, assess your work practices. If you get a rash, seek medical attention early.

Abbreviations

µg	Micrograms
ACGIH®	American Conference of Governmental Industrial Hygienists
CFR	Code of Federal Regulations
CO	Carbon monoxide
COSHH	Control of substances hazardous to health
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
LOD	Limit of detection
LOQ	Limit of quantitation
mL	Milliliter
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
PPE	Personal protective equipment
ppm	Parts per million
REL	Recommended exposure limit
SDS	Safety data sheets
TFM	3-trifluoro-methyl-4-nitro-phenol
TLV®	Threshold limit value
TWA	Time-weighted average
WEEL™	Workplace environmental exposure level

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Introduction

The Health Hazard Evaluation Program received a request from a government agency health and safety manager concerned with potential exposures when employees manually applied pesticides into rivers to control sea lamprey larvae. We visited the river application sites twice to learn about health and safety concerns, observe work processes and practices, and assess exposures to pesticides. We provided managers and employee representatives letters summarizing our activities and recommendations in August 2011, December 2011, and September 2012.

Pesticides Used in the River Application

Sea lampreys *(Petromyzon marinus)* are parasitic fish in the Great Lakes, the Finger Lakes, and Lake Champlain [EPA 1999]. Sea lampreys are controlled primarily through manual application of pesticides into streams and tributaries to kill the larvae. The pesticides are 3-trifluoro-methyl-4-nitro-phenol (TFM) and Bayluscide™. TFM is the primary pesticide; Bayluscide is used with TFM when TFM alone would pose too much risk to non-target organisms or would be cost prohibitive [EPA 1999]. An estimated 56,000 kilograms of TFM (CAS Registry Number: 88-30-2) and 1,000 kilograms of Bayluscide (CAS Registry Number: 1420-04-8) were applied in 2012 [Great Lakes Fishery Commission 2012]. In a typical treatment year, 30 to 40 U.S. tributaries receive applications of pesticides [EPA 1999]. Formulation types include TFM liquid concentrate (38%), TFM bar (solid), Bayluscide 70% wettable powder, Bayluscide 20% emulsifiable concentrate, and Bayluscide granular (3.2% and 5%) [EPA 1999; U.S. Fish and Wildlife Service 2004]. Information on the toxicity of TFM and Bayluscide is in Appendix A.

River Application

Effective pesticide application usually requires maintaining an optimal water concentration for 10–12 continuous hours. The three types of river applications are primary, maintenance, and supplemental. The operation may last up to 10 days. A primary application occurs at the most upstream point of the waterway so the pesticides flow downstream. Maintenance applications are performed downstream to maintain effective pesticide concentrations. Supplemental applications are made to still backwater areas and in low-discharge rivers to kill sea lamprey larvae and to prevent their escape into larger rivers [U.S. Fish and Wildlife Service 2004]. TFM liquid and Bayluscide wettable powder and emulsifiable concentrate are used in primary and maintenance applications. TFM liquid, TFM bar, and granular Bayluscide are used in supplemental applications. Although procedures and equipment differ with each application and pesticide formulation [U.S. Fish and Wildlife Service 2004], all require supervision and assistance of biological field technicians. These technicians prepare equipment, then transport, mix, and apply pesticides into the river. Technicians also analyze river water samples in portable laboratories to measure pesticide concentrations throughout a treatment period. Because pesticide concentrations in water can vary, continuous monitoring is necessary [U.S. Fish and Wildlife Service 2004].

About 38 employees work in two biological stations. Most of the employees work in 10-day periods throughout the season (April to October). Although standard operating procedures are in place for the use of these pesticides [U.S. Fish and Wildlife Service 2004], comprehensive exposure data have not been collected to assess applicators' potential health risks [EPA 1999].

Methods

First Visit

On August 8–9, 2011, we observed an operation to control sea lamprey larvae. The objectives of this visit were to identify potential health symptoms associated with pesticide use among applicators and to identify main routes of pesticide exposure. We met with managers, union representatives, and employees to discuss the request. We observed workplace conditions and work processes and practices at different application sites to understand the potential for exposure to the pesticides and other hazards. At each site, we held confidential medical interviews with employees to discuss their workplace practices, use of personal protective equipment (PPE), personal hygiene at work, and work-related health and safety concerns. We observed employees mixing and applying Bayluscide wettable powder and Bayluscide emulsifiable concentrate at maintenance applications and TFM liquid and TFM bars at supplemental applications. We used a TSI Q-TRAK Plus Monitor Model 8554 to measure carbon monoxide (CO) in a portable laboratory and portable workstation. Propane generators used to power laboratories and equipment could be a source of CO exposure.

Because we observed the potential for employee skin contact with TFM and Bayluscide, we decided to make a second site visit to assess dermal exposure. For this evaluation, we developed sampling and analysis methods for TFM and Bayluscide on surfaces (Appendices B and C).

Second Visit

The objectives of the second visit were to assess skin exposure and determine the effectiveness of protective gloves. On August 20–21, 2012, we observed employees mixing and applying TFM liquid and Bayluscide wettable powder at a primary application and TFM liquid, TFM bars, and Bayluscide granular at supplemental applications. We collected wipe samples for pesticides from work surfaces, employees' work clothing, and exposed skin. We also collected wipe samples from employees' hands to see if their gloves protected the skin from pesticides. Details of the sampling procedures can be found in Appendix B.

Document Review

We reviewed Occupational Safety and Health Administration's (OSHA) Form 300 Logs of Work-Related Injuries and Illnesses for 2008–2010. We also reviewed the updated 2011 medical clearance and surveillance program guide; pesticide safety data sheets (SDSs); heat stress guidance; the occupational, safety, and health plan chapter on PPE that was given to employees; and the written respiratory protection program. We reviewed an industrial hygiene report dated November 16, 2010, that evaluated employee exposures to some of the nonactive pesticide ingredients including isopropyl alcohol and amorphous and crystalline silica.

Results

Employee Interviews

We confidentially interviewed a convenience sample of 20 of 38 employees (permanent and temporary) who were present during our first visit. The average age was 39 years (range: 25–64 years), and the median tenure was 5.5 seasons (range: 2–29 seasons). Of these 20, 14 were employees who applied the pesticides, four were fish biologists, one was a physical science technician, and one was a supervisor. Most of these employees worked 10 days on duty (typically 8-hour day or night shifts), followed by 4 days off duty.

The interviewed employees were generally aware of the potential exposure routes to Bayluscide and TFM and potential health risks from these exposures (i.e., eye irritation and skin sensitization). Eleven employees reported a history of seasonal allergies, and two reported history of eczema prior to the current job or during the off season. Health problems reported by fewer than five employees that they associated with work included skin irritation with TFM, skin rash, and poison ivy.

All the interviewed employees reported taking scheduled breaks in the field ranging from 1–30 minutes, depending on the job task. Employees reported usually having access to drinking water and staying hydrated throughout the day. All interviewed employees reported washing their hands before eating. Hand washing techniques varied and included using hand sanitizer, hand wipes, river water, and self-provided water, along with soaps or waterless cleaners. Of 20 employees, 18 reported that they noticed pesticide on clothes or skin at some time during pesticide handling. Employees said their clothing usually became contaminated when they mixed or applied pesticides, or when they touched contaminated equipment. Some reported dermal exposure because gloves ripped or pesticide (or treated water) splashed onto unprotected skin (e.g., forearms).

Most of the interviewed employees reported wearing eye protection (safety glasses, goggles, or face shield) and chemical resistant gloves when mixing and applying pesticide. Two interviewed employees said they did not always wear gloves when working in the laboratories. Interviewed employees reported wearing a National Institute for Occupational Safety and Health (NIOSH)-approved full facepiece dual cartridge (particulate and organic vapor) respirator when using the Bayluscide wettable powder and Bayluscide granular. Also, the interviewed employees reported changing clothes, waders, or aprons when major contamination was visible. In addition, the interviewed employees mentioned that light-emitting diode headlamps helped them notice pesticides on their clothes or skin during the night shift.

Pesticide Application Observations

We saw employees handling TFM liquid, TFM bars, Bayluscide wettable powder, Bayluscide emulsifiable concentrate, and Bayluscide granular. However, the observations noted below focus on TFM liquid and Bayluscide wettable powder, the pesticides used in the largest quantities. All employees mixed and applied these pesticides outdoors.

3-Trifluoro-methyl-4-nitro-phenol Liquid Application

We observed employees applying TFM liquid with a powered pump during a primary application and several maintenance and supplemental applications. The largest quantity of TFM liquid used was at the primary application. Employees poured TFM from manufacturer prepackaged 5-gallon containers into unlabeled open vats before it was pumped into the primary application site. The primary application flow rate (1,500 milliliters per minute) was controlled by a butterfly valve. Employees cleaned the empty TFM containers with river water and stored them prior to disposal. We observed that TFM liquid spilled when employees were pouring it from 5-gallon prepackaged containers into a large vat. The employees placed a plastic liner on the ground to help contain these spills. Spilled pesticide was cleaned with water at the end of the shift, and this water was dumped into the river. Employees tracked TFM pesticide outside of the immediate work area to areas where food and water were stored as evidenced by yellow footprints on the cement floor. Visibly contaminated floors and equipment were cleaned with pressurized water at the end of the shift.

During supplemental applications, TFM liquid from 5-gallon containers was added to river water using a lower application flow rate (78 milliliters per minute) (Figure 1) by dripping TFM liquid into a graduated cylinder.

Figure 1. Manual application of the TFM liquid pesticide in a river at low flow rates. Photo by NIOSH.

3-Trifluoro-methyl-4-nitro-phenol Liquid Personal Protective Equipment

All application employees wore short or long sleeve shirts, long pants, waders, water resistant aprons, and Ansell Chemi-pro® gloves made of neoprene and natural rubber latex (12 inches long and 20-mil thick canners and handlers gloves model 27-224). Coveralls and rubber aprons were used by employees during the primary application, and most times used during low flow rate applications (employees considered the pesticide exposure potential to be low). Most employees wore safety glasses, goggles, or a face shield when applying TFM liquid. We saw one employee not wearing eye protection while pouring TFM liquid in the primary application. Most employees wore rubber safety boots, but we saw some wearing leather hiking boots that would be hard to clean. No respiratory protection was required or used for the handling of TFM liquid in primary, maintenance, or supplemental applications. Employees in the primary application wore hard hats as required by the land owner where the application was occurring, although not recommended by the label. All other PPE used by employees was recommended on the TFM liquid label [U.S. Fish and Wildlife Service 2004]. Specifically, the TFM liquid label [U.S. Fish and Wildlife Service 2004] recommended that handlers wear chemical-resistant gloves such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, polyvinyl chloride, or Viton®.

As suggested by the TFM liquid label, we saw employees washing pesticides off PPE with clean untreated water at the end of the shift during the TFM liquid primary application. We did not observe employees washing PPE after applying TFM liquid during maintenance or supplemental applications. We observed employees storing not washed and visibly contaminated PPE with personal items, potentially leading to cross contamination.

Bayluscide Wettable Powder Application

We observed employees mixing Bayluscide wettable powder into water before pumping it into a maintenance application site. The Bayluscide was prepackaged in a 3-pound plastic container. Employees uncapped the container and placed it underwater to fill the container. The operator then recapped the container and shook it to mix the water and powder. The operator then poured the Bayluscide mixture into a 100-gallon tank and discarded the container. Premixing the pesticide with water helped minimize the release of Bayluscide powder into the air. However, during the primary application of the Bayluscide wettable powder we saw a dust plume when the container was first opened. During the primary application, the Bayluscide/water mixture was directly pumped into the river. At the maintenance application site, the Bayluscide/water mixture was pumped to a perforated hose extending across the river.

Bayluscide Wettable Powder Personal Protective Equipment

Employees wore long sleeve shirts, long pants, waders, and Ansell Chemi-pro® gloves made of neoprene and natural rubber latex or all natural rubber latex. In addition, employees wore safety glasses and half-mask or full facepiece elastomeric respirator with organic vapor and N95 cartridges. The label recommended the use of rubber gloves (or water resistant), long sleeve shirt, shoes and socks when using the Bayluscide wettable powder [U.S. Fish and Wildlife Service 2004].

We observed employees not decontaminating respirators, gloves, hip boots, and waders before storing them. We observed employees storing respirators without placing them into sealed bags. Employees told us that there were no special handling instructions for storing used PPE, even when yellow pesticide stains were visible. In one instance we saw an employee placing waders with visible yellow stains onto the front seat of the agency truck. The pesticide label recommended rinsing gloves before removing them and washing contaminated clothing before reuse.

Figure 2. Manual pouring of the Bayluscide wettable powder pesticide into two large vats before it is pumped into a river. Photo by NIOSH.

Wipe Sampling and Cotton Glove Liners

Results of the wipe sampling of work surfaces, clothing, and skin are in Appendix D, Tables D1–D3. Some of the highest surface contamination levels were from surfaces with visible yellow stains during the primary application. Most skin surfaces that we wiped were contaminated with pesticides. Results for the cotton glove liners worn under the Ansell Chemi-pro® gloves are in Appendix D, Table D4. We sampled the gloves of three employees, each for two chemicals. No pesticides were found with the exception of one instance of TFM measured at a level between the limit of detection (LOD) and limit of quantitation (LOQ). The gloves on which we detected TFM were worn for 60 minutes; the other gloves had been worn 35 minutes.

Carbon Monoxide Monitoring

We spot measured CO concentrations during our August 2011 evaluation in a portable laboratory and a portable workstation. Both were using propane-powered electrical generators. Low CO concentrations (0–0.6 parts per million [ppm]) were measured inside the laboratory with the window closed, air-conditioning on, and the door closed most of the time. The workstation used to carry Bayluscide application equipment had two large doors that remained open at all times, no windows, no air-conditioning, and the generator exhaust was vented beneath the workstation. The CO concentrations in the workstation ranged from 0–200 ppm. Although there was only one instantaneous reading of 200 ppm, this suggests that employees working in this area could be overexposed to CO. Information on the health effects of CO and the occupational exposure limits (OELs) is presented in Appendix C.

Other Observations

We observed some employees storing their lunch boxes next to potentially contaminated PPE and placing beverages near pesticide equipment.

We did not see any technicians in the portable laboratories wearing safety glasses or chemical resistant gloves when using reagents or pesticide-treated river water. The employer had standard laboratory safety procedures requiring PPE use when handling reagents [U.S. Fish and Wildlife Service 2004]. We saw one employee eating and storing food in the laboratory.

The trailers or trucks used to transport pesticides and application equipment were equipped with spill kits. However, the trucks did not have an emergency eyewash station or access to clean water for hand washing (Figure 3). Although the employer provided reflective vests, road and traffic cones, and blinkers for employees, we did not see employees using this equipment.

Figure 3. Truck used to carry TFM liquid and application equipment to remote areas. Photo by NIOSH.

Some portable workstations were not equipped with fire extinguishers, CO monitors, or portable emergency eyewash stations or shower. One portable laboratory did not have a CO detector, and the fire extinguisher had not been inspected since 1996.

During both of our visits the outdoor temperatures were mild (in the mid-70's). However, on warmer days, workers may be at risk for heat stress and heat strain. In response to our recommendation to provide drinking water following our first visit, we noted during our second visit that water was provided during the primary application, but not on some of the supplemental applications.

Document Review

The OSHA Logs for 2008–2010 contained reports of 14 injuries, one illness, and one poisoning (eye). The OSHA Log did not contain any additional background information on the reported eye poisoning.

The updated 2011 medical clearance and surveillance program guide addressed potential health effects from TFM and Bayluscide exposure. It stated that the primary exposure pathway for TFM (liquid and bar forms) was dermal, and the exposure pathways for Bayluscide (wettable powder, granular, and emulsified concentrate) were dermal and inhalational (if dusty). The yearly medical surveillance program included training on identifying and treating symptoms associated with heat illness, animal bite wound care, and avoidance of ticks or contact with irritant plants such as poison ivy, oak, or sumac. Employees received a physical capability test that stimulated lifting, carrying, and emptying containers of lampricide (approximately 50 pounds).

The pesticide SDSs we reviewed were detailed and comprehensive. The heat stress guidance was comprehensive and appropriate for work outdoors in hot environments. The generalized PPE guidance provided to employees was comprehensive and included guidelines on eye protection for those with prescription glasses [U.S. Fish and Wildlife Service 1992].

The written respiratory protection program included all elements of the OSHA Code of Federal Regulations (CFR) Part 1910.134 but did not include suggested cartridge change out schedules. We reviewed the results of industrial hygiene air sampling conducted by consultants hired by the employer. The results showed employee exposures to isopropyl alcohol in the TFM liquid and crystalline and amorphous silica in the Bayluscide wettable powder were well below occupational exposure limits.

Discussion

One objective of this evaluation was to identify potential health symptoms associated with pesticide use. During medical interviews, fewer than five employees reported specific work-related health concerns. Health concerns mentioned that were consistent with pesticide exposure included skin irritation and skin rash, although these nonspecific symptoms have many causes.

Another objective was to identify main routes of pesticide exposure. Because some employees wore short sleeves, pesticides could splash onto their bare arms. Some employees used dermal PPE inconsistently, and some did not clean their PPE before reusing it. Some employees washed their hands with pesticide-treated river water, a practice that could further expose them to the pesticides both dermally and by ingestion. Because TFM and Bayluscide have low vapor pressure (meaning they do not readily evaporate at room temperature) [Dawson 2003; Hubert 2003], inhalation exposures of either pesticide is unlikely, unless it is aerosolized in some way (e.g., spills, splashes). We concluded that the main route of exposure was skin contact.

Another objective was to assess dermal exposures. We found pesticides on work surfaces, and employees' skin and clothing. Although there are no occupational exposure limits for surface contamination with these pesticides, our results highlight the need to improve practices to minimize skin exposure. Hand contamination may indicate that employees were touching contaminated surfaces with bare hands, reusing contaminated gloves, or not using protective gloves when necessary.

Another objective was to determine the effectiveness of protective gloves. TFM was found on one employee's gloves. Bayluscide contamination was not found. The fact that TFM was not detected on hand wipes of the sampled employee before and after using the glove liners suggests that the gloves used for TFM liquid adequately protected employees when used correctly. The gloves worn by employees are rated as excellent for isopropyl alcohol [Ansell 2011], an ingredient of TFM liquid [U.S. Fish and Wildlife Service 2004]. We are unaware of glove chemical compatibility information specific for TFM or Bayluscide. We recommend that the current gloves be replaced with gloves listed in the TFM liquid label to eliminate the risk of latex allergy from products containing natural rubber latex.

Respirators were required during the primary application when applying Bayluscide wettable powder. Employees wore full facepiece or half-mask elastomeric respirators equipped with combination volatile organic compound and N95 filter cartridges. There is no information on the efficacy of these respirator cartridges against Bayluscide, and the pesticide labels do not recommend the use of respirators. Prior air sampling found that exposures to crystalline and amorphous silica in the Bayluscide wettable powder were well below occupational exposure limits. Considering that application of Bayluscide wettable powder occurs during the summer months on potentially very hot days, wearing respirators places additional heat stress on employees. The level of respiratory protection could be reduced on the basis of the agency's review of protective standard operating procedures, good work practices, and improved engineering controls.

We saw employees transferring, handling, and mixing TFM liquid and Bayluscide wettable powder in open containers. Spills and dust from mixing could be reduced if enclosed equipment were provided. For example, the open mixing vats used in the primary application of TFM liquid could be enclosed and TFM liquid transferred by tube from prepackaged containers to the vats. The same could be done for the transfer and mixing of Bayluscide wettable powder in primary and maintenance applications.

We recommend the agency to use the developed sampling methodology to assess surface contamination as interventions in the workplace are implemented. Alternatively, control banding can also be used to assess interventions or even other hazards in the future, especially since TFM and Bayluscide do not have OELs. Control banding is a technique used to guide the assessment and management of workplace risks. Control banding helps employers select a control measure (for example dilution ventilation, engineering controls, containment, etc.) on the basis of a range or "band" of hazards (such as skin/eye irritant, very toxic, carcinogenic, etc.) and exposures (small, medium, large exposure). Some examples of how to successfully use control banding for TFM and Bayluscide are provided in Appendix E.

Conclusions

Skin contact appears to be the main route of employees' exposure to pesticides. We observed inconsistent use and inappropriate reuse of PPE, and inconsistent hand washing methods. We detected pesticides on work surfaces, personal clothing, and skin of employees. We observed the transfer, handling, and mixing of pesticides in open containers. We also measured a high CO peak concentration in a portable workstation.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the employer to use a labor-management health and safety committee or working group to discuss our recommendations 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 these pesticide application and monitoring sites.

Our recommendations are based on an approach known as the hierarchy of controls. 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 PPE may be needed.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Direct exhaust from power generators away from the portable workstations to reduce CO exposure.
2. Provide enclosed equipment for the handling and mixing of pesticides.
3. Install washing stations at primary application sites so that employees can clean their boots, PPE, and skin before they leave the application area.

Administrative Controls

The term administrative controls refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Develop procedures to clean PPE that is reused.
2. Provide clean water and soap at every work site for washing hands or skin after contact with pesticide or irritant plants.
3. Require employees to wash their hands with mild soap and water after contacting pesticides and before eating, drinking, chewing gum, using tobacco, or using the restroom. Waterless hand sanitizers are not effective at mechanically removing contamination.
4. Encourage employees who contact pesticides to change clothes and shower at the end of the shift.
5. Keep food and beverages away from pesticides.
6. Provide an emergency eyewash station in all portable workstations, trailers, and trucks. The American National Standards Institute recommends that the eyes be flushed immediately and thoroughly for at least 15 minutes using a large supply of clean water under low pressure [ANSI 2009].
7. Provide a portable emergency shower station or hoop decontamination wash system in portable workstations. These wash systems should be supplied with clean water.
8. Label vats that are used to mix or transfer pesticides.
9. Provide water or other hydrating fluids to employees (especially important in hot environments).
10. Provide fire extinguishers in all portable workstations and CO monitors in portable workstations with generators. Inspect and certify the fire extinguishers annually. Inspect the CO monitors annually to ensure their proper function following manufacturer recommendations for battery change out schedules.
11. Perform routine safety audits of work areas and stations.
12. Enforce road safety (e.g., use reflective vests, cones, and blinkers). Provide road safety equipment in all portable workstations, trailers, and trucks and train employees on the importance of following safety practices.
13. Encourage employees to report any health or safety concerns associated with job tasks to a supervisor. Employees with work-related symptoms should promptly seek medical attention from their healthcare provider.

Personal Protective Equipment

PPE is the least effective means for controlling hazardous exposures. Proper use of PPE requires a comprehensive program and a high level of employee involvement and commitment. The right PPE must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. PPE should not be the sole method for controlling hazardous exposures. Rather, PPE should be used until effective engineering and administrative controls are in place.

1. Follow all safety instructions listed on the pesticide labels, including using adequate PPE such as wearing safety glasses when applying or analyzing pesticides, wearing long sleeve shirts when applying pesticides, wearing chemical resistant gloves when applying or analyzing pesticides, and washing of PPE when contaminated.
2. Use neoprene, nitrile, or vinyl gloves that provide sufficient chemical resistance. Do not use gloves containing natural rubber latex.
3. Enforce consistent use, storage, and appropriate reuse of PPE.
4. Require the use of eye protection when handling Bayluscide wettable powder.
5. Review the need for and level of respiratory protection worn by employees after implementing engineering control recommendations.

Appendix A: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limit or ceiling values. Unless otherwise noted, the short-term exposure limit is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA permissible exposure limits (PELs) (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH recommended exposure limits (RELs) are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2014]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the threshold limit values (TLVs), which are recommended by the American Conference of Governmental Industrial Hygienists (ACGIH), a professional organization, and the workplace environmental exposure levels (WEELs), which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of

the published, peer-reviewed literature. These OELs are not consensus standards. TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2014]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2013].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 1,500 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs like that described in Appendix E.

Below we provide the OELs for the compounds we measured, if any, as well as a discussion of the potential health effects from exposure to these compounds.

Pesticides

The Environmental Protection Agency regulates pesticide use [EPA 1999] and requires pesticide labels and standard operating procedures [EPA 1999; U.S. Fish and Wildlife Service 2004]. TFM liquid is labeled dangerous and poisonous, while TFM bar and Bayluscide emulsifiable concentrate are labeled dangerous [U.S. Fish and Wildlife Service 2004]. Bayluscide emulsifiable concentrate is labeled to be handled with caution [U.S. Fish and Wildlife Service 2004].

3-Trifluoromethyl-4-nitrophenol

TFM is the primary chemical used to control sea lampreys. Human health effects have not been associated with the handling of this pesticide, and there is limited animal toxicological data in the SDS and technical sheets. Precautions for TFM are based on animal toxicology [U.S. Fish and Wildlife Service 2004]. From animal studies we know that ingestion exposure to TFM may result in irritation of mucous membranes, and may be harmful or fatal. Skin contact with TFM in animal studies has caused severe irritation but not skin sensitization. TFM may cause central nervous system depression in animals with nausea, vomiting, dizziness, and drowsiness. TFM is not considered a carcinogen, and no significant reproductive effects were observed in animal studies. There are no occupational exposure limits for TFM.

Bayluscide

Bayluscide is a wettable powder, granule mixture, or concentrated liquid consisting primarily of niclosamide ethanolamine salt. Animal studies [U.S. Fish and Wildlife Service 2004] show that inhalation may cause upper respiratory tract irritation, coughing, and a nasal discharge. These studies also showed that skin contact caused mild irritation. Ingestion caused adverse effects to the gastrointestinal and respiratory tracts and a hunched posture in some animal species [U.S. Fish and Wildlife Service 2004]. Niclosamide ethanolamine salt is not considered a carcinogen, and no significant reproductive effects were observed in animal studies. The only applicable occupational exposure limits are for particulate not otherwise classified as total dust (15 milligrams per cubic meter) and the respirable dust fraction (5 milligrams per cubic meter) [OSHA 2006].

The Bayluscide wettable powder contains magnesium silicate (also known as talc) and other compounds in amounts less than 1.1% by volume including crystalline silica (≤ 0.1%). The Bayluscide granular contains amorphous silica, polyoxyethylene-polyoxpropylene block copolymer, and other compounds in quantities less than 4% by volume. None of these inactive ingredients is a carcinogen or teratogen [U.S. Fish and Wildlife Service 2004]. The only applicable occupational exposure limits for the Bayluscide wettable powder and Bayluscide granular are for particulate not otherwise classified as total dust (15 milligrams per cubic meter) and the respirable dust fraction (5 milligrams per cubic meter) [OSHA 2006].

The liquid Bayluscide concentrate contains N-methyl-2-pyrrolidone, and nonionic alkanolamide surfactant. Animal studies show that skin contact with the concentrated liquid caused moderate to severe irritation, dermatitis, blisters, cracking, and edema, allergic skin reactions (i.e., skin sensitization), and severe eye irritation. N-methyl pyrrolidone is listed on California Proposition 65 as a chemical that causes developmental toxicity [U.S. Fish and

Wildlife Service 2004]. Neither of these inactive ingredients is considered a carcinogen [U.S. Fish and Wildlife Service 2004].

Carbon Monoxide

CO is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials such as gasoline or propane fuel. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, or nausea. Symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. If the exposure level is high, loss of consciousness may occur without other symptoms. Coma or death may occur if high exposures continue [NIOSH 1972]. The display of symptoms varies widely from individual to individual, and may occur sooner in susceptible individuals such as young or aged people, people with preexisting lung or heart disease, or those living at high altitudes.

Exposure to CO limits the ability of the blood to carry oxygen to the tissues by binding with the hemoglobin to form carboxyhemoglobin. Once exposed, the body compensates for the reduced bloodborne oxygen by increasing cardiac output, thereby increasing blood flow to specific oxygen-demanding organs such as the brain and heart. This ability may be limited by pre-existing heart or lung diseases that inhibit increased cardiac output.

The NIOSH REL for CO is 35 ppm as a full-shift TWA exposure, with a ceiling limit of 200 ppm that should never be exceeded [NIOSH 1992]. NIOSH has established the immediately dangerous to life or health value for CO as 1,200 ppm [NIOSH 2014]. This value is the concentration at which an immediate or delayed threat to life exists or that would interfere with an individual's ability to escape unaided from a space. The ACGIH recommends an 8-hour TWA TLV of 25 ppm [ACGIH 2014]. ACGIH also recommends that exposures never exceed five times the TLV (thus, never to exceed 125 ppm) [ACGIH 2014]. The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure [29 CFR 1910.1000].

Appendix B: Sampling Methods

Wipe Sampling Procedure

We used 4 × 4 inch polyester Texwipe AlphaWipes® (ITW Company) prewetted with 4 milliliters (mL) of 50% isopropyl alcohol and 50% water and stored individually in 9-ounce glass jars with polytetrafluoroethylene-lined screw caps (Figure B1). Wearing clean gloves, we opened the wipe container and removed the wetted wipe. We used a 10 centimeter × 10 centimeter disposable cardboard template when possible to outline the surface that we sampled. For uneven or irregular surfaces, we estimated the sample area. Using one side of the wipe we wiped the surface using repeated horizontal motions. We folded the wipe in half and wiped the same surface area, but this time wiping at a right angle (vertically) to the first wiping motion. For hands, we asked the employees to wipe their hands for approximately 30 seconds as if they were cleaning their hands. We placed the used wipe in a labeled container and kept it cold until analysis.

Figure B1. Wipe sampling on skin of employee after applying pesticides. Photo by NIOSH.

Cotton Glove Sampling Procedure

We gave 100% cotton gloves (MCR Safety) to some employees at the start of their shift to wear beneath a new pair of their regular work gloves. We asked employees to wash their hands before wearing these glove liners. At the end of their work we assisted employees in carefully removing their regular work gloves to avoid touching the inner cotton gloves. Cotton gloves were placed in 9-ounce glass jars with a polytetrafluoroethylene-lined screw caps and kept cold until analysis. Hand wipes were also used before and after the use of cotton gloves for some of the employees to identify skin contamination before and after the use of protective gloves in the field.

Appendix C: Analysis Method for Niclosamide and 3-Trifluoromethyl-4-nitrophenol

These methods were developed for this project and should be considered experimental.

Wipe and Glove Sample Preparation

Wipe and glove samples were extracted in the laboratory with methanol (10 mL for a wipe sample, 120 mL for a glove sample). After shaking the extract for 60 minutes, approximately 3 mL of extract was filtered through a 13-millimeter polytetrafluroethylene syringe filter then transferred to a 4-mL amber glass vial. An aliquot of the filtered extract was analyzed by high performance liquid chromatography with a photodiode array detector.

Sample Analysis

A single chromatographic method was developed to provide separation of TFM and niclosamide (active ingredient of Bayluscide). The LODs and LOQs for wipes and gloves are shown in Table B1. The analytical range was up to 6,000 micrograms (µg)/sample for TFM and 1,800 µg /sample for niclosamide. TFM had a recovery of > 98% and a precision of > 97%. Niclosamide had a recovery of > 99% and a precision of > 98%.

Table C1. Limit of detection and quantitation values for glove and wipe media

	Niclosamide*, (µg)		TFM, (µg)	
	Glove	Wipe	Glove	Wipe
LOD	1	0.3	3	0.7
LOQ	3.3	1.0	10	2.3

*Active ingredient of Bayluscide

The sample analysis method parameters were as follows:

- Instrument: Waters 2690 separations module
- Detector: Waters 996 photodiode array detector
- Column: Zorbax Eclipse XDB-C18, 3.0 × 250 millimeters, 5 micrometers
- Column flow rate: 0.5 mL/minute
- Column temperature: 86°F (30°C)
- Injection volume: 10 microliters
- Detection wavelength: 334 nm for niclosamide and 294 nanometers for TFM
- Run time: 24 minutes
- Elution time: 14.6 minutes for niclosamide and 7.1 minutes for TFM

The following gradient was used for the mobile phase:

- 7 minute – 40% mobile phase 1/60% mobile phase 2
- 8 minute – 10% mobile phase 1/90% mobile phase 2
- 15 minute – 10% mobile phase 1/90% mobile phase 2
- 16 minute – 40% mobile phase 1/60% mobile phase 2
- 24 minute – 40% mobile phase 1/60% mobile phase 2

Mobile phase 1 = deionized water with 0.1% phosphoric acid
Mobile phase 2 = 100% methanol

Calibration and quality control was performed using analytical standards prepared from neat reference materials of 99% TFM (Sigma-Aldrich N27802-5G, Lot MKBD8547V) and 99.5% niclosamide (ChemService PS-1207, Lot 459-96A). Stock solutions were prepared in methanol.

Appendix D: Tables

Table D1. Wipe sampling on employees' clothing for pesticides on August 20–21, 2012

Work location	Employee number	Sample location	Niclosamide* (μg/sample)†	TFM (μg/sample)†
Primary application of TFM liquid and Bayluscide wettable powder	2	Rubber apron	1.5	86
	2	Hard hat	2.6	3.6
	3	Gloves on surface	ND‡	37
	4	Back shirt	1.3	13
	5	Boot wader	ND	41
	6	Inside respirator†	5.2	ND
	6	Cuff of the shirt	260	ND
	8	Inside boots	4.8	ND
	12	Bottom of boots	93	340
	17	Apron front	4.0	20
	17	Inside of hard hat	29	3.8
	20	Inside of apron	ND	(1.1)**
Supplemental application of TFM liquid	5	Sole of shoe	ND	8.5
	13	Goggles†	ND	67
	13	Apron	ND	99
	13	Cuff of the shirt	ND	40
	14	Back of shirt	ND	ND
	15	Glasses†	ND	ND
	16	Inside hip boots	ND	(2.0)
	16	Shirt	ND	100
	22	Cap cloth	ND	ND
	22	Boot front top	ND	ND
Supplemental application of TFM bars and Bayluscide granular	23	Inside waders	ND	ND
	24	Inside waders	ND	ND
	25	Inside waders	(0.65)	(1.8)
LOD			0.3	0.7
LOQ			1.0	2.3

*Niclosamide is the active ingredient of Bayluscide.

†The area of the wipe sample was approximately 100 square centimeters because many surfaces were irregular.

‡ND = not detected, below the LOD.

**Values between the LOD and LOQ are shown in parentheses. There is more uncertainty associated with these values than with levels above the LOQ.

Table D2. Wipe sampling on surfaces for pesticides on August 20–21, 2012

Work location	Sample location	Niclosamide* (µg/sample)†	TFM (µg/sample)†
Primary application of TFM liquid and Bayluscide wettable powder	Lunch box #a	ND	ND
	Lunch box #b	ND‡	ND
	Insulated water container spout‡	(0.89)§	ND
	Nozzle on titrator†	38	23
	Yellow stain on concrete floor before leaning	3.4	1,700
	Concrete floor after cleaning	ND	62
	Truck #5, driver inside door handle†	1.4	(1.4)
	Trailer back door handle†	(0.33)	ND
	Kit/tool box with PPE stored	1.7	10
	Truck #5, river floor pedals	1.4	18
	Cooler handle†	(0.88)	ND
Parking lot central location	Truck #1, steering wheel†	ND	(2.0)
	Trailer handle on door†	ND	ND
	Truck #2, driver seat	1.1	2.5
	Truck #2, steering wheel†	2.8	14
	Truck #2, driver outside door handle	(0.68)	(1.5)
	Truck #3, steering wheel†	(0.42)	3.4
	Truck #3, driver outside door handle	ND	ND
	Truck #4, passenger door handles	ND	ND
	Truck #4, passenger seats	0.9	2.9
Supplemental application of TFM liquid	Truck # 6 tailgate, where lab work was done	ND	ND
	Trailer handle door†	ND	ND
	Lab bench top mobile lab	ND	(1.4)
	Door handle mobile lab†	ND	ND
	Lab keyboard	ND	ND
Supplemental application of TFM bars and Bayluscide granular	Boat steering wheel†	ND	12
	Boat throttle†	ND	8.5
	Boat motor control	ND	6.3
	Boat bilge, end of shift	(0.59)	210
LOD		0.3	0.7
LOQ		1.0	2.3

*Niclosamide is the active ingredient of Bayluscide.

†The area of the wipe sample was approximately 100 square centimeters because surfaces were irregular.

‡ND = not detected, below the LOD.

§Values between the LOD and LOQ are shown in parentheses. There is more uncertainty associated with these values than with levels above the LOQ.

Table D3. Dermal wipe sampling for pesticides on August 20–21, 2012

Worksite	Employee number	Sample location	Niclosamide* (µg/sample)†	TFM (µg/sample)†
Primary application of TFM liquid and Bayluscide wettable powder	1	Hands	1.2	3.9
	1	Hands, after washing	1.6	8.2
	2	Neck, yellow stained skin	ND‡	79
	3	Forearm	(0.88)	(1.2)
	6	Hands, after washing	270	11
	7	Hands, beginning of shift	1.7	ND
	9	Hands, beginning of shift	ND	ND
	9	Hands, after washing	2.3	(1.4)
	10	Hands, before cotton liners	2.5	ND
	10	Hands, after cotton liners	1.7	ND
	11	Hands, before cotton liners	6	8
	11	Hands, after cotton liners	1.4	(0.81)
	12	Hands, after cotton liners	7.4	ND
Supplemental application of TFM liquid	13	Hands	ND	110
	14	Hands	ND	9.0
	15	Neck	ND	ND
	16	Hands	ND	85
	16	Hands, after washing	2.4	6.2
	16	Forearm, after washing	1.1	11
	17	Hands, after washing	6.4	12
	17	Neck, after washing	ND	ND
	19	Hands	150	58
	20	Hands, after washing	3.4	8.2
	21	Back of the hand	ND	ND
	21	Forearm	ND	ND
	22	Hands	ND	6.8
Supplemental application of TFM bars and Bayluscide granular	23	Hands	ND	85
	24	Hands	ND	78
	25	Forearm	ND	(1.4)
LOD			0.3	0.7
LOQ			1.0	2.3

*Niclosamide is the active ingredient of Bayluscide.

†Surface area for most skin sampled was approximate 100 square centimeter surface area except for hands. Hands were wiped for approximately 30 seconds.

‡ND = not detected, below the LOD.

§Values between the LOD and LOQ are shown in parentheses. There is more uncertainty associated with these values than with levels above the LOQ.

Table D4. Cotton gloves used under natural rubber gloves on August 20–21, 2012, analyzed for pesticides

Employee number	Time gloves were used (minutes)	Niclosamide* (µg/sample)	TFM (µg/sample)
10	60	ND†	(2.3)‡
11	36	ND	ND
12	34	ND	ND
LOD		1.0	3.0
LOQ		3.3	10

*Niclosamide is the active ingredient of Bayluscide.

†ND = not detected, below the LOD.

‡Values between the LOD and LOQ are shown in parentheses. There is more uncertainty associated with these values than with levels above the LOQ.

Appendix E: Control Banding Methods

The traditional approach to protecting worker health measures employee exposures to potentially hazardous agents, compares them to occupational exposure limits, and then determines if existing control measures provide adequate protection. Reliance on this approach has become increasingly difficult because of the growing number of potentially hazardous materials in the workplace that do not have occupational exposure limits. Control banding is a technique used to guide the assessment and management of workplace risks. It uses the solutions that experts have developed previously to control occupational chemical exposures and suggest them for other tasks with similar exposure situations. Control banding methods are also called control banding tools or toolkits. More information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/.

There are many fully developed control banding methods or toolkits. Although they may use different terminology, all of these methods have some things in common. The first step is to evaluate the health hazard of the material, then determine the potential exposure. These two steps are used to determine the control band for the task. These control banding methods have been developed for inhalation and dermal hazards and for specific industries such as nanotechnology.

We selected three of the most commonly used control banding tools to evaluate inhalation and dermal exposure hazards associated with mixing Bayluscide wettable powder with water in a vat and pouring TFM liquid into a vat. We chose these tasks because they involved employees handling the largest amount of pesticides. The same process can be used for other chemical hazards that may arise.

The first control banding method we used is called COSHH Essentials and was developed by the Health and Safety Executive (http://www.hse.gov.uk/coshh/essentials/index.htm). COSHH stands for control of substances hazardous to health. To evaluate the health hazard of the material we selected an appropriate risk phrase (R-phrase), sometimes called a hazard statement (H-code). The R-phrase describes the special risks associated with chemical substances. These R-phrases are defined by the European Union and are found internationally in SDSs. With the implementation of the Globally Harmonized System of Classification and Labelling of Chemicals, hazard statements (H-codes) will eventually replace the R-phrases; however, at this time the control banding toolkits still use the R-phrases. On the basis of the R-phrase the control banding tool places the material into one of five groups labeled A–E, with A being the least hazardous group and E the most hazardous group. To determine the exposure potential of the task, we decide the dustiness or volatility (how quickly it evaporates at room temperature) of the chemical, choosing from low, medium, or high levels of dustiness or volatility. We also decide on the quantity used or generated (small, medium, or large quantity). The COSHH Essentials tool then combines the results from these two steps and assigns the task to one of four control strategies.

The second control banding method we used was the International Chemical Control Toolkit from the International Labor Organization (http://www.ilo.org/legacy/english/protection/safework/ctrl_banding/toolkit/icct/). Using this method, the evaluator assigns the chemical of concern to a hazard respiratory group on the scale from A (safest) to E (most dangerous). Like the COSHH Essentials, this method uses the dustiness or volatility of the chemical, the quantity used, and R-phrases to make this selection.

The third control banding method used was the chemical management guide for dermal hazards developed by the German agency Deutsche Gesellschaft für Internationale Zusammenarbeit (now GIZ), available at http://www2.gtz.de/dokumente/bib/07-0702.pdf. This method uses R-phrases to classify chemicals that cause damage through skin contact or absorption into five risk groups (classified A through E). Depending on the amount used the hazard category would be basic (lowest hazard), advanced (medium hazard), or special (highest hazard).

We used the COSHH Essentials online toolkit and the International Chemical Control Toolkit to evaluate the respiratory hazards associated with mixing Bayluscide wettable powder with river water and pouring TFM liquid into a vat. We used the GIZ chemical management guide dermal toolkit to evaluate the recommended level of protection for both tasks. Neither the COSHH Essentials nor the International Chemical Control Toolkit has fully developed a dermal exposure method.

Using Control Banding for Two Tasks

Task One: Mixing Bayluscide Wettable Powder with Water

On the basis of the SDS, we used the most hazardous ingredient (crystalline silica) and the most prevalent ingredient (niclosamide ethanolamine salt) in Bayluscide wettable powder to identify the following R-phrases:

- R-20/21/22: harmful by inhalation, in contact with skin, and by ingestion
- R-22: harmful if swallowed
- R-34: causes burns
- R-36: irritating to the eyes
- R-36/38: irritating to eyes and skin
- R-50/53: very toxic to aquatic organisms

We decided that Bayluscide wettable was a fine light powder (very dusty) and that a medium quantity was used in the task. Using this information the COSHH Essentials and the International Chemical Control Toolkit assigned a health hazard band of “C” to this task, meaning that it involves handling a “more hazardous substance.” Both methods recommended control level 3, “Containment” (i.e., fully enclosing the process), and suggested substitution with less hazardous materials as the primary means to reduce the hazard. The International Chemical Control Toolkit also recommended diluting concentrated pesticides: http://www.ilo.org/legacy/english/protection/safework/ctrl_banding/toolkit/icct/pesticides.htm.

Using the GIZ chemical management guide skin toolkit, Bayluscide wettable powder is classified a skin hazard group C, "more hazardous substances," on the basis of the following risk phrases:

- R-34: causes burns
- R-36/38: irritating to eyes and skin

We decided that a medium quantity of Bayluscide was used and that employees sometimes immersed their hands in pesticide-treated river water during the task. We decided that the duration of the task was short, under 15 minutes per day. Using this information, the GIZ chemical management guide recommended an advanced control approach involving elimination or substitution, applying administrative or engineering controls, and using PPE. If substituting a less hazardous chemical or engineering and administrative controls were not possible, PPE was recommended to protect potentially exposed skin.

Task Two: Pouring TFM Liquid into a Vat

We used the following R-phrases obtained from the SDS for TFM:

- R-10: flammable
- R-22: harmful if swallowed
- R-24: toxic in contact with skin
- R-38: irritating to skin
- R-41: risk of serious damage to eyes
- R-50/53: very toxic to aquatic organisms

The SDS did not list a boiling point for TFM liquid. However, because TFM has low volatility, we assumed it would behave more like a solid in a liquid. We decided that a large quantity was used because employees poured 900 gallons of TFM liquid into the river water over an 8-hour period. COSHH Essentials and the International Chemical Control Toolkit assigned this task to a hazard group of C, "more hazardous substances," and recommended a control approach of level 3, "Containment."

To evaluate the dermal exposure the GIZ chemical management guide dermal toolkit assigned TFM liquid to skin hazard group C, based on its R-phrase that it was toxic in contact with skin (R-24). We decided that a large quantity pesticide (900 gallons) was used and that employees could immerse or wet their hands and forearms during the task. The duration of the task was short, under 15 minutes a day. Using this information, the GIZ toolkit recommended an advanced control approach involving elimination or substitution, applying engineering or administrative controls, and using PPE. If substituting a less hazardous chemical or engineering and administrative controls were not possible, PPE was recommended to protect potentially exposed skin.

Control Banding Discussion

Although control banding has yet to be fully tested, these methods offer ways to assess risks and choose relevant control measures to reduce occupational exposures. Controls recommended by control banding methods may still need to be reviewed by a health and safety professional to ensure that the control strategy and how it is implemented are appropriate. Additionally, using control banding for some pesticide applications may not be appropriate because some pesticides are extremely toxic, have multiple exposure routes, and are aerosolized and sprayed over a large area. Likewise, tasks that involve multiple chemicals, chemicals that may have more hazardous health effects when mixed, and chemicals with insufficient toxicity data could result in an incorrect estimation of exposure potential. We believed that these control banding methods were appropriate for these pesticide applications because of (1) the limited application area, (2) the limited number of pesticides or other chemicals used, and (3) the amount of available environmental toxicology data. Using these control banding methods, the recommended controls were similar to our recommendations in this report (e.g., use enclosed equipment for handling pesticides [containment] and PPE).

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