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Personal Protective Equipment Requirements for Pesticide Handlers—Conflicts between Toxicity-based and Exposure Assessment-based Approaches

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Introduction

In 1992 the U.S. Environmental Protection Agency (EPA) published final revisions to its pesticide labeling requirements (40 CFR Part 156) and worker protection standard (40 CFR Part 170);[1,2] the worker protection standard became effective in 1995. To comply with revised labeling requirements, pesticide manufacturers must include worker protection statements on their pesticide labels. A statement is made in the 1992 supplementary information section that the EPA considers personal protective equipment (PPE) the primary means of controlling pesticide exposures.[1,2] Consequently, product-specific statements are required describing the PPE needed during pesticide handling activities. Pesticide handling activities, defined by the EPA in section 170.3 of the worker protection standard, include not only pesticide mixing, loading, and applying, but also flagging, disposing of pesticides or pesticide containers, and repairing contaminated mixing, loading, or application equipment.

The EPA requires that PPE described on a pesticide label be based on the product's acute toxicity as determined from animal testing and must meet minimum PPE requirements specified in section 156.212 (e). The EPA's minimum PPE requirements vary depending on the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) toxicity category of a formulated product. The four FIFRA categories are equivalent to toxicity ratings and range from extremely toxic (category I; signal word: danger) to practically nontoxic (category IV; signal word: caution).[3]

A pesticide label is the law. With few exceptions, section 170.240 (a) of the worker protection standard requires a pesticide handler to "use the clothing and personal protective equipment specified on the labeling for use of the product."[2] Although exposure conditions vary among the different pesticide handling activities, only one PPE ensemble complying with the EPA's minimum requirements is provided on many product labels.

Using a toxicity-based approach to set PPE requirements for a pesticide differs from an approach of selecting PPE based on an assessment of the exposure conditions of a pesticide handling activity. Learning a pesticide's toxic properties and occupational exposure limits, determining routes and types of exposures, estimating inhalation and skin exposures, and monitoring task durations are important aspects of an exposure assessment-based approach. Two pesticide application situations are described here showing conflicts that can arise between toxicity-based and exposure assessment-based approaches for selecting PPE, and recommendations are provided for avoiding similar conflicts.

Spraying Paraquat Outdoors

The contact herbicide paraquat dichloride (CAS number 1910-42-5) was used by Plant Protection and Quarantine (PPQ) officers of the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service to treat fields, gardens, and idle parcels of land infested with witchweed. Witchweed is one of the most serious crop pests of Africa, the Middle East, and Far East countries. USDA's Witchweed Eradication Program started in 1957 with a goal of eradicating witchweed from eastern sections of North Carolina and South Carolina, the only locations in the western hemisphere where this parasitic annual is known to occur.[4,5]

PPQ officers applied paraquat using hand-operated knapsack sprayers and all-terrain vehicles (Figure 1), farm tractors, and high cycle tractors with spray booms. The paraquat-containing herbicide mixed and sprayed by the officers was Gramoxone® Extra. Gramoxone Extra is a restricted use pesticide containing 37 percent paraquat dichloride and 63 percent inert ingredients.[6] It also contains a stenching agent to give it an offensive odor and an emetic agent to cause vomiting by anyone ingesting the chemical. The PPE required when handling Gramoxone Extra was "coveralls over a long-sleeved shirt and long pants; waterproof gloves; chemical-resistant footwear plus socks; protective eyewear; chemical-resistant headgear for overhead exposure; a chemical-resistant apron when cleaning equipment, mixing, or loading; and a dust and mist filtering respiratory (NIOSH approval number prefix TC-21C)."[6]

Exceptions to the EPA's worker protection standard include wide-area public pest control programs sponsored by government entities.[2] Therefore, despite the minimum PPE and work clothing specified on a pesticide's label, PPQ officers are not legally bound to use them.

PPQ officers apply paraquat during the summer in North Carolina and South Carolina, after witchweed seeds have germinated and plants have emerged. Consequently, environmental conditions during paraquat applications are usually hot and humid. Because of the concern

FIGURE 1. All-terrain vehicle with a spray boom operated by a USDA PPQ officer to apply paraquat to a field infested with witchweed.

to not impose any additional heat stress burden on the applicators, their supervisors did not require them to wear any of the PPE or work clothing described on the Gramoxone Extra label. The director of the Witchweed Eradication Program was concerned about a potential for inhalation exposures to paraquat, but she new that no PPQ officer would wear a respirator and endure the concurrent heat stress burden without evidence that a respirator was needed. A National Institute for Occupational Safety and Health (NIOSH) health hazard evaluation (HHE) was requested so the results of air sampling measurements made during paraquat applications would suggest whether respirators were needed.[7]

Paraquat

Paraquat is used to control or suppress a broad spectrum of emerged weeds and is also used as a crop desiccant at harvest.[6] Paraquat is nonvolatile with an essentially negligible vapor pressure of <0.0000001 mmHg at 68°F.[8] It occurs as colorless and odorless crystals and is marketed as aqueous solutions containing surfactants.[9] Paraquat is an irritant of the eyes, mucous membranes, and skin; ingestion causes fibroblastic proliferation in the lungs.[10] However, there is no evidence that inhalation exposures in occupational settings cause the rapid, progressive pulmonary fibrosis and injury to the heart, liver, and kidneys that occur from ingestion.[10] Paraquat's toxicity in the lung is apparently dependent on the size of inhaled particles. Respirable particles (i.e., particles with mass median diameters less than 5 μm) have been reported to be from five to six times more toxic than nonrespirable particles.[9]

Eye exposure to paraquat concentrate can cause corneal and conjunctival inflammation. The inflammation develops gradually and can progress to maximum damage from 12 to 24 hours after exposure. The seriousness of an eye injury following paraquat exposure may go unnoticed until after the damage has progressed to corneal scarring.[11]

Most herbicide poisonings result from unintentional spills or intentional ingestion,[12] and the consequences of ingesting paraquat are in marked contrast to its irritant effects. Many fatal accidental and suicidal ingestions of paraquat have been reported.[10,13] The prognosis for paraquat toxicosis is generally grave, and there is no antidote. Effective treatment of paraquat poisoning depends on rapid gastrointestinal emptying to prevent excessive absorption.[12] Death from paraquat ingestion is caused primarily by progressive pulmonary fibrosis leading to respiratory failure.[14] Death has followed accidental ingestion of small amounts of liquid concentrates containing 29 percent paraquat, and in one case the quantity of liquid concentrate consumed was reported to have been not more than three-quarters of a teaspoon (approximately 3 ml).[15]

Paraquat-containing herbicides and desiccants are FIFRA category I pesticides.[16] The NIOSH recommended exposure limit (REL) and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for respirable paraquat are both an 8-hour time-weighted average (TWA) of 100 $\mu g/m^3$.[17,18] ACGIH has also recommended a TLV–TWA of 500 $\mu g/m^3$ for total paraquat.[18] The NIOSH REL has a skin notation; the ACGIH TLV does not. After a literature review in 1978, ACGIH deleted their skin notation because of a lack of evidence suggesting that systemic toxicity resulted from dermal absorption of paraquat.[9] The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) is an 8-hour TWA of 500 $\mu g/m^3$ for respirable paraquat with a skin notation.[19] The NIOSH immediately dangerous to life or health air concentration for paraquat is 1000 $\mu g/m^3$.[8] The results of a laboratory study to assess the mutagenic potential of Gramoxone (a formulation of 20% paraquat) using a battery of five different eukaryotic systems showed mutagenicity in all bioassay systems tested. A conclusion was made that paraquat should be regarded as a mutagenic herbicide.[20]

Results and Discussion

Air samples for both total and respirable paraquat were collected during eight paraquat spraying applications lasting from 14 to 144 minutes. Personal samples were collected on PPQ officers as they used hand-operated knapsack sprayers and drove all-terrain vehicles, farm tractors, and high cycle tractors with attached spray booms. Regardless of the application method used, paraquat was mixed and applied at a solution strength of 0.5 percent (w/w) or less. All air samples and field blanks were analyzed for paraquat according to NIOSH Method 5003.[21] Paraquat was not detected on any sample.

Compared with ingestion and skin exposure, pesticide inhalation during outdoor applications contributes little to total body burden.[22] Researchers who evaluated paraquat applications with

knapsack sprayers lasting several hours a day also concluded that essentially no inhalation exposure to paraquat is associated with this application method.[23–25] A similar conclusion was made by a researcher who evaluated inhalation exposures of workers operating tractor-mounted, low boom spray equipment in orchards.[15]

An explanation for the low inhalation health risk associated with spray applications of paraquat is that the droplets released from the nozzles of knapsack sprayers and booms are so large that they settle quickly and therefore do not remain aerosolized.[15,24,26,27] Paraquat's nonvolatility reduces any remaining risk even further. The likelihood that aerosol drift could occur during a PPQ application was reduced by an operating procedure of applying paraquat only on days when winds were calm.

Recommendations

Based on the results of the NIOSH HHE, the following PPE recommendations were made for the handling of paraquat by PPQ officers:

- A full-facepiece shield should be worn to protect an officer's eyes, face, and mouth from spills and splashes during mixing, loading, and maintenance activities. Because skin exposure—and especially hand exposure—is likely during these activities,[28,29] a chemical-resistant apron, disposable sleeve protectors, and chemical-resistant gloves should also be worn.
- A full-facepiece shield should be worn to protect an applicator's eyes, face, and mouth during knapsack spraying; chemical-resistant gloves should be worn to protect the applicator's hands.
- PPE is unnecessary during applications using all-terrain vehicles or tractors, but PPE (i.e., a full-facepiece shield, a chemical-resistant apron, disposable sleeve protectors, and chemical-resistant gloves) should be carried with application equipment for times when it needs to be repaired at a work site.
- A set of clean clothing and shoes should be stored in each applicator's vehicle to wear in case his or her clothes get wet unexpectedly from a spill or splash, or from a leaking knapsack sprayer.

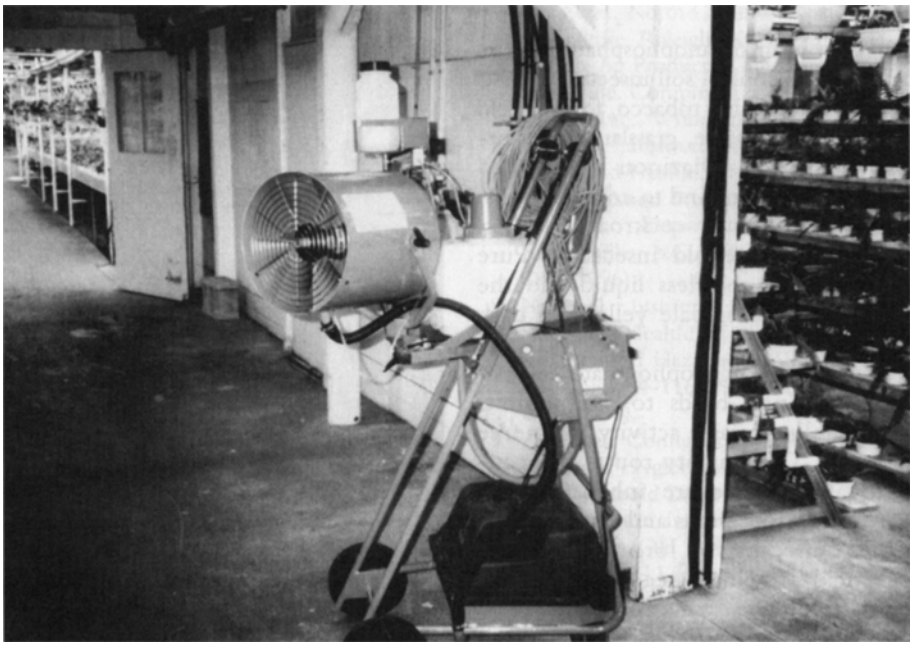

FIGURE 2. Electric coldfogging machine used to apply pesticides inside a greenhouse. The machine's timers can be programmed to automatically start and stop an application, which minimizes a pesticide handler's risk of exposure.

Diazinon Applications in a Greenhouse

Diazinon (CAS number 333-41-5) is one of many insecticides used to control greenhouse pests. During a NIOSH HHE at a commercial greenhouse company, air sampling was done during diazinon applications using high volume spraying equipment and coldfogging machines.[30,31] Some pesticide handlers prefer to use a coldfogging machine (Figure 2) because it can be programmed to start and stop automatically, therefore eliminating the need for a handler to be in a greenhouse section during its treatment. On occasion, however, an applicator would enter during an application to ensure that the equipment was operating correctly.

The diazinon-containing insecticide coldfogged by the company's applicator was Clean Crop Diazinon AG500 Insecticide, an emulsifiable concentrate formulation containing 48 percent diazinon, 36 percent aromatic petroleum derivative solvents, and 16 percent inert ingredients.[32] According to the product label, the PPE required when handling this restricted use pesticide is "long-sleeved shirt and long pants; chemical-resistant gloves such as: barrier laminate, butyl rubber, nitrile rubber or viton; and shoes plus socks."[33] This is the minimum PPE required by the EPA for a FIFRA category III pesticide.[1]

The PPE listed on the material safety data sheet (MSDS) for Diazinon AG500 Insecticide that appeared under a heading "EPA Handler Requirements" differed from the PPE listed on the product label. (When the manufacturer learned of this discrepancy, the problem was immediately corrected.) According to the MSDS, the PPE required during handling was "*coveralls over short-sleeved* shirt and *short* pants; chemical-resistant gloves such as: barrier laminate butyl rubber, nitrile rubber or viton; *chemical-resistant footwear* plus socks; *protective eyewear; chemical-resistant headgear for overhead exposure*; and *chemical-resistant apron when cleaning equipment, mixing, or loading.*"[32] This PPE resembles the minimum required by the EPA for a FIFRA category I or II pesticide, except that the EPA also requires the use of respiratory protection when handling such pesticides.[1] This section of the manufacturer's MSDS also contains a statement that these PPE requirements "address handler/applicator requirements under FIFRA and may differ from what is felt necessary to address a cleanup, needs during formulation/manufacturing or other times of involvement with the product."[32]

Diazinon

Diazinon is an organophosphate insecticide used to control soil insects and pests of fruits, vegetables, tobacco, forage, field crops, range, pasture, grasslands, and ornamental plants. Diazinon is also used for seed treatment and to control grubs, nematodes in turf, cockroaches, flies, and other household insects.[16] Pure diazinon is a colorless liquid and the technical grade is pale yellow to dark brown.[9]

Like other organophosphate insecticides, diazinon binds to and inhibits acetylcholinesterase activity of nerve tissue.[34] The primary routes of occupational exposure are inhalation and skin absorption. Signs and symptoms of acute poisoning by organophosphate insecticides include headache, nausea, chest tightness, wheezing, increased sweating, salivation and tears, stomach cramps, and diarrhea.[9,34] Direct eye exposure to aerosolized organophosphate insecticides can cause early miosis and blurred vision.[34] Asphyxia from respiratory failure is the immediate cause of death in fatal cases of organophosphate poisoning.[34]

Depending upon formulation, diazinon-containing insecticides are classified as FIFRA category II or III.[16] The NIOSH REL and the ACGIH TLV for diazinon are 100 $\mu g/m^3$ (8-hour TWA).[17,18] The TLV has a skin notation, showing diazinon can be absorbed through skin in sufficient quantities to cause toxicity to other parts of the body. OSHA did not have a PEL for diazinon before the 1989 Air Contaminants Standard, which was vacated by the 11th Circuit Court of Appeals in 1992. Therefore, there is no federal standard for this pesticide. However, some states operating their own OSHA-approved job safety and health compliance programs may enforce the 100 $\mu g/m^3$ limit.

Results

Air sampling was conducted in a greenhouse with passive ventilation during a 1-hour spraying application and a 4-hour coldfogging application of diazinon. All air samples and field blanks were analyzed for diazinon according to NIOSH Method 5600.[35] The PPE worn by the pesticide handler during the spraying application included an unhooded chemical-resistant suit, chemical-resistant gloves and boots, and a half-facepiece respirator (Figure 3).

FIGURE 3. Deficiencies with the PPE worn by this pesticide handler when spraying diazinon inside a greenhouse included a poorly fitting half-facepiece respirator, respirator filters that had not been replaced for weeks, no hood to protect against overhead exposure, and no eye protection.

The air concentration of diazinon in the greenhouse section during the spraying application ranged from none detected (two locations within the section but away from the treated area) to approximately 300 $\mu g/m^3$.[30,31] Four-hour TWA air concentrations of diazinon measured during the coldfogging

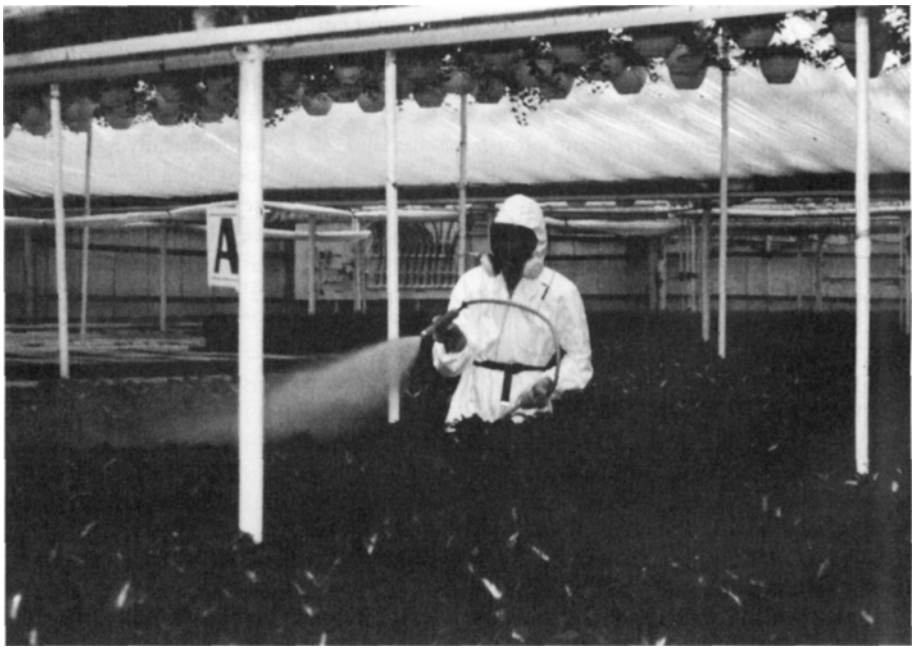

FIGURE 4. The pesticide handler corrected the deficiencies described in Figure 3 by wearing a full-facepiece respirator selected from the results of fit testing, fresh respirator filters, and a hooded chemical-resistant suit.

application ranged from 700 to 3000 $\mu g/m^3$.

Recommendations

Based on the results of the NIOSH HHE, the following PPE recommendations were made for the handling of diazinon by greenhouse applicators:

- During a spraying application, an applicator should wear a hooded chemical-resistant suit, chemical-resistant gloves and boots, and a full-facepiece respirator with pesticide cartridges (Figure 4).
- When entering a greenhouse section during a coldfogging application, an applicator should wear a hooded chemical-resistant suit, chemical-resistant gloves and boots, and any respirator with an assigned protection factor of at least 30 (i.e., a negative-pressure, full-facepiece respirator with high efficiency filters, a powered air-purifying respirator with tight-fitting facepiece and high efficiency filters, or a self-contained breathing apparatus).[36]

Conclusion

Given the variety of handling activities and exposure conditions that can be associated with any pesticide, successfully recommending a single generic PPE ensemble that will be appropriate for all situations is unlikely. In the first example, requiring pesticide handlers to wear coveralls over a long-sleeved shirt and long pants, chemical-resistant footwear, and a respirator was unnecessary and would have increased the workers' risk for developing heat-related illness. Following publication of the NIOSH final report on the paraquat-related HHE in 1996, the EPA allowed the manufacturer of Gramoxone Extra to reduce the PPE requirements for handlers of this herbicide.[37] According to the current label for Gramoxone Extra, "applicators and other handlers (other than mixers and loaders) must wear a long-sleeved shirt and long pants, waterproof gloves, and shoes plus socks." Besides wearing the PPE required by applicators, mixers and loaders must also wear a face shield and a chemical-resistant apron.[37]

In the second example, air sampling for diazinon during its application inside greenhouse sections showed that airborne concentrations were high enough to warrant the wearing of respiratory protection. However, respiratory protection was not listed with the required minimum PPE listed on the product label or MSDS.

Recommendations

- Pesticide handlers should be aware that conflicts between toxicity-based and exposure-based approaches for selecting PPE can lead to situations where use of the PPE listed on a product label will not assure appropriate worker protection for all exposure conditions and handling activities. A revision to the PPE requirement of the worker protection standard [section 170.240 (a)] giving pesticide handlers flexibility in the selection of PPE may be warranted.
- Pesticide manufacturers should include information on product labels warning pesticide handlers that the listed PPE is the minimum required by the EPA, is based on the formulated product's acute toxicity as determined from animal testing, and may not be appropriate for all exposure conditions and handling activities.
- PPE requirements listed on a product label and its MSDS should be identical.
- Pesticide handlers should independently evaluate the PPE needs for each pesticide handling situation. Because respirators provide varying levels of protection, handlers who work in greenhouses should be especially careful to base respiratory protection selections on the results of air sampling measurements.

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