How can we successfully protect the sprayer operator?

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Summary

Operator safety is of paramount importance during the spraying process. Unfortunately not all farmers or sprayer operators share the educator's view on the need for risk mitigation. Attitude of the individual and their manager determines whether or not safe practices are followed. There are many new developments in application technology which can reduce the risk of exposure to pesticides. This paper reviews where risks are greatest and how technology can address important issues. Research has shown that not all technology is helpful, for example, air filtration in tractor cabs leaves much to be desired, engineering controls such as closed transfer systems can slow down the filling process resulting in such devices not being used. Tank rinsing devices on the other hand speed up the "spraying process" and reduce operator contamination. ISO standards on tank cleanliness are raising farmer awareness for good practices, particularly with new "safer products" used in very small, concentrated amounts. Surveys have shown that the influence of engineering controls on Personal Protective Equipment use varies state by state. New educational programmes are necessary to educate operators on the relative merits of new technology to reduce exposure to pesticides.

Introduction

The use of pesticides in agriculture introduces occupational hazards and health risks to personnel involved in handling and application tasks. The main hazard to operator health is direct chemical exposure, particularly during mixing and loading. Both engineering controls (induction bowls, closed transfer systems, etc.) and personal protective equipment or PPE (coveralls, gloves, etc.) reduce exposure to pesticides.

Most people working with pesticides recognize that clothing provides some degree of protection, but they have long resisted wearing these garments (Stone et al. 1993, Eggertson and Perkins 1993, Partridge et al. 1995, Weingart et al. 1996). Heat stress, however, is the primary reason cited for non-compliance with PPE regulations. The lack of thermal comfort is especially important for wearers of full body coveralls. Additional research on these materials is needed to establish predictive models for PPE that better explain the tradeoffs between protection and comfort. Perry et al (2000) in a survey of operators' attitude to risk found a disturbing number of applicators believing that most pesticides would not be put into the marketplace if they were dangerous to health. Familiarity breeds contempt!

The sprayer operator is at risk from splashes of dilute pesticide during the washing out of the sprayer, when folding booms and from spray drift, (Turnbull et al 1985; Landers 1989). The time taken to measure and decant pesticides and for adequate washing out of the pesticide containers and the sprayer tank after use is expensive and may well encroach upon the time available for spraying. If the operator hurries these tasks then the chance of contamination increases. Landers and Hill (1996) outlined several engineering solutions for reducing the risk of sprayer operator contamination that could be adopted by farmers. Closed transfer systems, carbon cab filters and tank rinsing systems are cited as good engineering controls to reduce the contamination hazard. As an example of engineering control effectiveness, Brazelton and Akesson (1987) showed that the number of pesticide related illnesses among mixer/loader workers in California decreased by 50% after the introduction of closed transfer systems.

Previous work measuring the exposure of operators of agricultural spraying equipment has included studies on the use of open tractors compared to enclosed cabs (Abbott, et al., 1987, Mick, 1973, Lunchick, *et al*., 1988). Samples analyzed for pesticides had been taken from the protective clothing and from surfaces on the exterior and interior of the enclosed cabs or open tractors. Lunchick, *et al*. (1988) concluded that enclosed cabs are superior to open tractors, reducing operator dermal exposure by a factor of six. The American National Standards Institute (ANSI), in cooperation with the American Society of Agricultural Engineers (ASAE) published advisory definitions, testing procedures, and performance criteria for enclosed cabs for pesticide applications incorporating respiratory protection, Standards S525-1.1 and S525-2 (ASAE 1998). The test cabs have a circulating internal air supply which has been purified using a series of filters or other devices, and lowers the airborne contamination inside the cab by reducing the concentrations of particulate matter, aerosols, and other vapors. The performance criteria set by ANSI/ASAE for enclosed cabs is the reduction of pesticides levels flowing through the air filter to 1/50 of the level outside the cab. This standard approximates the use of a full-face respirator.

The US Environmental Protection Agency (EPA) Worker Protection Standard for Agricultural Pesticides does not require the use of engineering controls. However, it allows an agricultural pesticide handler to omit some of the label required personal protective equipment when using closed transfer systems or enclosed cabs that have built-in respiratory protection, EPA (2000) and EPA, (1993). In a public registration notice to manufacturers, producers, formulators and pesticide product registrants, the EPA (2000) has indicated that in the future, engineering control use may be required as a way to mitigate the risks associated with handling and applying certain pesticides. The type of controls required will depend on the magnitude of the risk and the potential effects from exposure to the pesticide. When comparing studies of operator exposure, particularly dermal exposure, reviewers must be aware of ecological and engineering fallacies, EPA (2007). The "ecological fallacy" is the mistaken assumption that all members of a group have the same characteristics as the group at large. The "engineering fallacy" is the mistaken assumption that all work practices and equipment within a scenario are in fact the same.

85% of total water resources in the U.S. are in the form of groundwater aquifers and this water provides drinking water for about 50% of the population. Groundwater contamination in North America, by domestic and industrial wastes from point sources, such as hazardous waste sites and illegal dumping, has created a great deal of attention (Wilkinson, 1991). Agricultural pesticides entering groundwater are likely to represent a relatively minor source of pollutants entering groundwater. Sophisticated equipment has enabled the detection of minute traces of pesticide residue, and the rate of advance in analytical techniques will soon result in the ability to trace just a few molecules of pesticide in a sample of water.

Farmers' assessments of different kinds of risk within a farm management strategy are a trade off with profitability, according to Lowe et al (1990). Whilst many farmers expressed strong concern over environmental and personal health hazards, financial factors were more important; many farmers prefer to run the risk of detection than invest in high cost pollution technology. A linear program model was developed by Bretas and Haith (1990) to determine an income-maximizing set of management activities for a cash-crop farm subject to groundwater quality standards for pesticide contamination. The research model compared the levels of crop production and income with the optimum use of pesticides. The results indicated that a trade-off between farm income and groundwater quality may be significant.

Engineering controls

Engineering controls can be used on many areas of the sprayer in an attempt to reduce operator contamination, (Landers et al 2000, Helms and Landers, 2001, Landers 2004) A second paper, Solutions for safer spraying accompanies this paper and provides greater detail on individual components.

When loading a sprayer, closed transfer systems allow concentrated pesticide to be moved from the original shipping container to the sprayer mix tank with minimal or no applicator contact. Induction bowls are hoppers attached to the side of the sprayer that allow pesticides to be added to the tank without the applicator climbing up onto the sprayer. Pesticides are poured into the induction bowl and water rinses the bowl and carries the pesticide to the spray tank.

Direct injection of pesticides allow pesticides to be mixed directly with water in the sprayer plumbing system rather than in the main spray tank. The pesticide is pumped from its container and mixed with the water either in a manifold or at the main water pump. Only clean water is held in the main tank of the sprayer.

Cleaning sprayers and containers offer potential hazards to the operator. Tank rinse systems comprise a clean water supply tank mounted to the sprayer and one or more rotating discs or nozzles mounted inside the main sprayer tank. These systems are designed for in-field rinsing of the sprayer, reducing time, rinsate and the risk of operator contamination. Container rinse systems consist of a rinse nozzle and bowl that traps the container washings (rinsate).

Reducing contamination at the sprayer boom is equally important. Many smaller farmers still use manual boom folding, an area of potential contamination. Hydraulic, cable or pneumatic folding systems reduce contamination considerably. Diaphragm check valves installed at each nozzle prevent droplets from dripping onto the operator or the ground by using a spring-loaded rubber diaphragm to close off the flow of liquid once the system pressure drops. Contamination can also occur when operators change or unclog nozzles during an application. Multiple nozzle bodies (or turret nozzles) allow operators to switch between nozzles with a turn of the nozzle body rather than having to unscrew or undo a threaded or a bayonet fitting. Low drift nozzles also reduce tractor/sprayer contamination, particularly at the boom.

Providing adequate wash water is essential (and often required). A simple container with a hand-operated valve can be mounted on the side of the sprayer to provide clean water for hand washing and personal hygiene.

Reducing operator contamination while driving the tractor is also important. Carbon filtration systems are used to remove pesticide odor and pesticide-laden mist from the fresh air used in a tractor or self-propelled sprayer cab. Preventing contamination of the cab interior also requires the removal of protective clothing before entering the cab. A simple locker or compartment mounted to the side or front of the sprayer can be used to store protective clothing.

Engineering control surveys

A study was conducted by Landers et al (2000) of application equipment manufacturers and distributors, state level pesticide regulatory officials, pesticide applicator training coordinators, and state pesticide inspectors or agents. The survey was carried out to determine the current level of use and understanding of engineering control methods and the application of engineering controls available in the USA. Mailing lists for the engineering control survey were derived from several sources, including trade and professional organizations.

The survey results indicate that with a few exceptions, most spray equipment manufacturers are not providing engineering controls as standard equipment. For the most part, manufacturers are offering several engineering controls as options. Farm operators appear to have some awareness of engineering controls, but are reluctant to use them despite their availability. Two questions arise from this observation. If engineering controls are optionally available, what will encourage farmers to purchase an engineering control? How do we persuade manufacturers and farmers, to buy into safety and the related costs of engineering controls? Manufacturers should be encouraged to supply a wide array of basic engineering controls for their spray equipment and to promote them on economic and safety grounds. Federal or state government may need to prescribe engineering controls on the pesticide label.

The survey also points out that engineering control education is deficient. PAT coordinators have developed very little written material on the adoption of legislation requiring engineering control use, but discussions tend to be general (one paragraph or less). Very few states have detailed engineering control educational materials available to farm operators or pesticide applicators. In a similar vein, engineering control training for pesticide applicators and extension agents/educators is somewhat limited. Development of web-based engineering control resources and training modules can help to fill this void, educating farm operators, pesticide applicators, and extension agents/educators on the benefits of engineering controls.

Another question arising from our research is what is the best combination of personal protective equipment (PPE) and engineering controls that should be used to maximize safety.

Most states do not require the use of engineering controls stricter than demanded by the federal government. Labeling that requires the use of engineering controls should be considered.

Written materials and training programs for applicators and extension agents/educators is somewhat limited. Work needs to be done to develop web-based information resources and training materials to provide adequate engineering control information and training to pesticide applicators and educators.

Engineering control use in the field is relatively low. Most engineering controls are used on 25% or less of the farms. The development of nationwide extension educational resources will improve awareness of engineering controls among educators and growers alike, helping to create a demand to satisfy market developments offered by manufacturers. A reduction in operator exposure should result from these efforts.

The California Department of Pesticide Regulation conducted a survey of 43 sealed pesticide transfer devices (closed transfer systems) in use between 2001 and 2002, Fong (2003). They visited three major types of system: suction extraction, container breach and direct drop/gravity feed. The systems were surveyed as to their compliance with the Director's criteria. They identified a general set of problems that all closed systems had at least one of. These problems included non-standardised container interfaces, problems with container rinsing, measuring difficulties and system complexities.

Non standardised interfaces and container rinsing are inter-related since the removal of pesticide or rinsate is accomplished by the same means. Fine measurement is impossible with systems that totally destroy the container such as the Goodwin box and Captain Crunch systems. System complexity is not necessarily a problem of the closed transfer system, more a problem due to inadequate training of the operator or emergency response teams who have no indication as to where to turn off a device.

The use of closed transfer systems for Category 1 liquid pesticides in California has been law since 1974. The regulations also allow personal protective equipment (PPE) exemptions to be granted with category II and category III pesticides when using a closed transfer device. Rutz (1987) concluded that the debate continued in the 1980's over their usefulness, the training of employees to use the systems was cited as a major reason. The belief existed that closed transfer systems do not improve safety and they would not use a device if it were not the law. Jacobs (1987) posed the question, risk reduction through the use of closed systems: an attainable goal? He suggested the effectiveness of closed transfer systems has been limited in accommodating the large variety of containers, human errors and equipment failures; sentiments echoed by Fong (2003) in his report.

Landers (1989) suggested that encouragement should be given to the pesticide industry and its associations to have the foresight and courage to go to better packaging. A golden opportunity exists for everyone to improve the logistics of spraying, reduce contaminated waste and improve their public image. He recommended that guidelines or criteria must be laid down to advise on the design of closed transfer systems. It is interesting to note that the American Society of Agricultural Engineers (ASAE) is still working on a draft Standard, started in the early 1990's and to which there has been little progress to date. Without a set of design standards it makes it very difficult for companies to develop a new closed transfer system for the global market. Formalising the California design criteria into a regulatory requirement might help as a good start for designers in the United States market.

Adoption of engineering controls

A survey of 702 pesticide applicators was conducted in three states from 2001 to 2003 to examine the use of engineering controls and personal protective equipment (PPE) and the link between these two protective strategies, Coffman et al (2007). The survey assessed the level of adoption of 16 different types of engineering controls and 13 types of PPE, how the engineering controls were used in conjunction with PPE, and whether applicators were aware that these two types of protective measures are linked. Results showed that use of engineering controls is increasing as 8 out of 16 engineering devices were adopted by more than 50% of the respondents. Respondents also reported a high level of PPE use. Nonetheless, most pesticide applicators were not aware that the two protective measures are linked and that use of engineering devices can reduce the amount of PPE they wear. The findings indicate a need for an integrated approach combining both engineering controls and PPE in educational programs for pesticide users. Size of operation, application equipment, and type of crops were found to influence adoption of engineering controls. Applicators working on larger farms, users of boom and hydraulic sprayers, and growers of field crops are more likely to adopt engineering devices. There is still much research to be done on improving the uptake of devices to protect the operator.

Pesticide residue in cabs survey

A study by Kline et al (2003) investigated the surface levels of pesticides in samples taken from various interior and exterior locations on tractors and commercial spraying equipment. The study also examined the potential efficacy of air-filtered cabs in reducing operator exposure.

Four enclosed tractor cabs had air inlets inside the cabs for filtering and circulating the cab air. The inlet and outlet louvres were mounted in the roofline of the cabs, either above the windshield or the side windows. A fifth tractor was an open tractor that was regularly used to pull a sprayer in fruit orchards. Three self-propelled sprayers were chosen. The fresh air inlets for the filtering and circulation systems for the three self-propelled sprayers were external to the operator cab. All the enclosed cabs were original equipment. Carbon filter replacement during the spraying season occurred when the operator detected the odor of chemicals in the cab interior.

Chemical residue wipe samples were collected from areas in the cab including inlet vent louvres to air filtration systems, air outlet vent louvres into the operator cabs, steering wheel (or center hub) and gauge areas, and the inside and outside of cab windshields and the underside of the tractor or spray rig seats. Fabric seats were vacuumed using a hand held vacuum pump. In the four sets of wet wipe samples from the windshields tested, all 18 chemicals that were tested for were present. Three chemicals, atrazine, diazinon, and carbaryl, were present in all of the wet wipe samples from windshields.

The results of the wet wipe samples taken from the bottom of the seats show that six pesticides were found in each of the five samples, chlorpyrifos, picloram (acid analysis technique), atrazine, diazinon, carbaryl, and alachlor. The larger number of pesticides found in all of the samples, Table 1, suggests that the area under the operator's seat is not cleaned as well as other surfaces when the equipment is washed. The total amount of pesticides found under the operator's seat was also generally higher than what was found on the windshields.

Samples taken from the fabric seats on two of the self-propelled sprayers and one of the tractors had the largest concentration of pesticides. This was probably due to the fabric seats acting as dirt sinks where dust and chemicals collect, which could then be released into the cab environment at a later time.

The contamination of steering wheels and seats is problematic in several ways. Operators could be the primary source of contaminating these areas, and further investigation of their attire, work practices, and training is needed. Because all operators would have contact with these surfaces, they could be unknowingly exposed to chemicals

When comparing chemical analysis results for the samples taken from the steering wheel and gauge areas, and under seat areas, the tractor without a cab did not have a higher level of total chemicals detected than the tractors using enclosed cabs. This suggests that thoroughness and regularity of cleaning of the tractors, regardless of whether an enclosed cab is used, is an important factor when evaluating operator exposure due to residual pesticides left on the equipment. Washing and cleaning of enclosed cabs was not done consistently on the commercial sprayers and tractors in this study. Cabs that had not been cleaned regularly, except during winter maintenance, showed higher levels of chemicals in the sampled areas. As noted previously (Lunchick, *et al*. 1988, ASAE Standards, 1998), an enclosed cab system offers greater protection for the operator during application of pesticides. Further documentation of cleaning methods, thoroughness, and frequency would be important variables in future studies.

Sample Number	Total Pesticide Detected (μg) for wipes, μg/g dust for seats	Description
33	2.081	– Patriot. [External fresh air inlet for air circulation system, in roof line above windshield]. Outlet vent into cab, above seat to the right.
34	1.509	– Patriot. Outlet vent into cab, above seat to the left.
35	1.543	– Patriot. [External fresh air inlet for air circulation system, in roof line above windshield]. System inlet vents outside of cab, above windshield in roof line.
36	6.198	– Patriot. [External fresh air inlet for air circulation system, in roof line above windshield]. INTERNAL cab air circulation system - inlet to system, right side of cab.
37	5.984	– Patriot. [External fresh air inlet for air circulation system, in roof line above windshield]. INTERNAL cab air circulation system - inlet to system, left side of cab.
38	85.075	– Patriot. Vacuumed from cloth seat.

Table 1 Pesticide residues found on Patriot self-propelled boom sprayer

The performance of carbon beds in the air filtering systems was inconsistent. In many cases, more types of pesticides or at higher concentrations were present on the louvred outlets from the air filtering system, than were present on the inlet louvres. This would suggest that the carbon beds are retaining pesticides and releasing them into the cab environment at a later point in time after the carbon bed has become saturated. There was no evidence to suggest that the filtering systems that drew their inlet air from within the cab itself performed any better or worse than air filtering systems that drew fresh air from external cab vents.

Great concern arises when high levels of pesticides are found on steering wheels and seats of tractors. Whilst the tractor is used for spraying, presumably the operator continues his normal practice, e.g. wearing personal protective equipment. If the tractor is used for other farm activities, such as baling hay or mowing grass, then the operator may not wear protective clothing and therefore be exposed to higher levels of pesticides. An interim measure to protect the operator may be to use disposable fabric seat covers over smooth seat surfaces.

Tractor cab design has improved by leaps and bounds over the past decade. A number of tractor manufacturers entered the millennium with “spray-safe cabs” only to withdraw the claim within months due to worries over litigation. Are carbon filters effective? The tractors bounce along dusty fields, filters lose their efficiency as the carbon particles settle and filters clog with dust particles. Is filter replacement/maintenance satisfactory when filters are changed only when the operator can smell pesticides?

Sprayer cleaning

When sprayer operators have finished spraying for the day, they should rinse out their sprayer tank. Currently, they return to the farmyard, use a hosepipe to fill the tank and should return to the field to empty out the tank. This takes time and subjects the operator to possible contamination. Often this results in the job not being carried out correctly leading to short-cuts being taken, such as removing the tank drain plug which results in point-source pollution. Regular washing out of a crop sprayer is also necessary to prevent build up of deposits or carry-over of injurious products to another crop. The degree of cleaning will depend on many factors, the pesticide product being used, the type of cleaning solution e.g. water versus decontamination solution, and the type of cleaning device, e.g. hand brush versus power washer.

Taylor and Cooper (1988) considered the problem of decontaminating a small 600 litre (158 gallon) sprayer. Trials using pesticides showed interesting results, 83.6% of remnants were found in the pump, controls and pipework and only 16.4% in the tank. Research, by Balsari and Airoldi (1998), shows that sprayers retain large amounts of pesticide solution. Depending on the size and design of the sprayer, there can be nearly 6 gallons of solution left in an airblast sprayer's plumbing system. In their survey of Italian fruit farms they found 59% of the growers used the remnants in the tank for the next treatment. In 19% of the cases it was disposed of in the field and 19% disposed of around the farm buildings. Their survey of cereal growers showed that 52.7% of farmers disposed of rinsate onto the ground near farm buildings. This high figure is alarming, it demonstrates that growers choose not to spend time returning to the field with rinsate, preferring to dispose of contents near the rinsing water supply at the farm buildings.

The volume of tank washings produced when cleaning out spraying equipment can be reduced significantly by using an efficient flushing system. A tank rinse systems consist of a clean water supply tank mounted to the sprayer and one or more rotating discs or nozzles mounted inside the main sprayer tank. Water is pumped from the clean water tank to the rinse nozzles where the water is sprayed around the inside of the spray tank. These systems are designed for in-field rinsing of the sprayer so that the tank washings can be applied to the field and reduce the amount of time spent traveling to and from the farmyard. A tank rinse system can be purchased as an option on some sprayers or as an add-on kit. A grower could install a simple system fairly easily. Using a rotary flushing disc fitted into the sprayer tank to enable cascading water to flush the tank, Jeffrey (1991) conducted trials using chelated manganese and found that flushing twice, each of two minutes duration, using 30 litres (8 gallons) of water, resulted in 1.06% of the original concentration remaining.

Sprayer washing, both internally and externally has gained much popularity in European research sectors, due primarily to environmental concerns, and has led to an ISO standard being created, ISO 22368, Pt II. (Wehmann, 2006). This standard was published in 2004 to encourage and propose how cleaning devices fitted on crop sprayers should be assessed.

Cooper et al (1998) showed that correct operation of the sprayer during the flushing operation is crucial if contamination of sensitive crops is to be avoided, all valves fitted to the sprayer must be operated to ensure thorough rinsing.

Balsari et al (2006) shows that the type of sprayer, the type of nozzles fitted and environmental conditions affect external deposits on a sprayer. Tower shaped air assisted sprayers, fitted with hollow cone nozzles operated at higher temperatures proved to be the worst at depositing the most pesticide onto the outside of the sprayer.

Cooper et al (2006) showed that low pressure washing systems, fitted to some sprayers for external cleaning in the field typically remove 33% of external deposits compared to hot or cold high pressure systems in many farmyards and typically capable of removing 95%. The handbrush was food but is labour intensive. At Cornell University in Ithaca, our fruit sprayers are waxed with car polish pre-season and this allows for easy, low pressure rinsing with a hose.

Ramwell and Johnson (2002) investigated the presence of 13 pesticides on the external surfaces of boom sprayers. Pesticides were detected with the greatest frequency and at higher doses on the boom, the nozzles and the tank with five pesticides being detected at >1000ug/cm^2 ten of the 13 pesticides were detected at > 10 ug/cm^2 on the tractor body. Ramwell et al (2006) concluded the sprayer boom contributes approx. 60% of pesticide loading during external washing compared to around 25% from the outside of the tank.

Pesticide waste from tank washing is a problem! The time taken to rinse out the sprayer and return to the headland of the field one has been spraying could take a long time and therefore be expensive in labor costs and missed spraying opportunity. The operation of rinsing out a sprayer tank with a water hose is putting the operator at risk from splashes of pesticide. Contaminated water may be applied to the treated crop, recognizing that the efficacy of the previous application of pesticide may be impaired.

Education

Focused training courses are needed, so much change and development is occurring within pesticide application, particularly within application technology. The current system of extension delivery presents information in short, intense bursts, for example, a visiting researcher is one of a number of speakers on the annual up-date programme, 45 minutes to update everyone. A concise, concentrated approach is needed as the current operator licensing and credit system leaves much to be desired. Spraying is a practical task, it requires practical skills which should be tested in a practical examination. Whilst this remains a challenge due to the shear numbers of operators involved, the next best instruction has to be in-depth courses with monitoring/tests.

Traditional methods of teaching are still extremely valuable, recent developments in technology provide an additional aid to teaching and learning, providing different ways of communicating, manipulating and handling information, Landers (2003). The challenge is for researchers to cascade their valuable research information to the end-user with a degree of impact. In Spring 2007, a new 1-$^1/_2$ day in-depth training course on better spray application techniques was introduced to help grape growers in New York state address the 6E's of crop protection within sustainable viticulture. The course is intended to improve grower's knowledge of spraying techniques with an in-depth training course, 1 day in a classroom setting, and a ½ day follow up with a practical hands-on field class. The course was sponsored by the NY Farm Viability Institute and targeted, in the first year, at 96 grape growers across the state who attended a total of 6 classes. In 2008, the course will be aimed at both apple and grape growers. The grape industry, for example, is a rapidly expanding industry in New York, with many vineyards located in watershed areas. The course will help growers reduce pesticides via hands–on training and will improve grower's profitability. This innovative course is unique, it is a first in the state, providing an intensive, applied, 11/2 day course. The courses were held in the grower's home regions and entitled "Effective spraying of vineyards" the aim being to:-

improve their knowledge of spraying techniques - leading to better deposition and less drift

improve timeliness of application - resulting in better disease and insect control

reduce off-target drift - keeping them within the law

show them how to modernize their existing sprayer

inform them of new developments in sprayer design - keeping them up-to-date

help them potentially to reduce pesticide use by 30% - 40%, - improving their profitability.

The European Community and the European Crop Protection association have just launched TOPPS – Train the Operators to Prevent pollution from Point Sources. The objectives include EU wide guidelines on best practices, training frameworks, stewardship projects initially through 8 member states. The main thrust is to develop information sharing and common training to standards which will harmonise training across four regions.

Sustainable farming has developed rapidly in a very short time. Most farmers are keen to conduct their businesses within a sustainable environment, taking care of their employees and ensuring they provide a good future for their families. Sustainable agriculture provides a golden opportunity for educationalists to provide support in helping growers attain their goals. The ever-increasing demand for quality food, produced from quality crops ensures an on-going need for grower education. The thee E's of sustainability, Environmentally sound, Economically viable and socially Equitable must be combined with the three E's of crop protection, i.e. Effectiveness, Efficiency and the Environment if we are to obtain continued success.

Conclusions

Across the world there are some operators fortunate enough to be provided with personal protective equipment, yet in hot, humid conditions wearing PPE can be most unbearable. The protection of the operator via engineering controls still needs to be further explored, it is very important to find the best compromise between wearing PPE and using an engineering control. Does an operator using a closed transfer device, for example, still have to wear full PPE?

Field observations of most closed transfer systems show that they reduce sprayer output and are often abandoned in pursuit of improved timeliness.

There is a need to develop rinsing protocols in the USA if we are to eliminate point source pollution from both internal and external deposits on crop sprayers.

Sustainable farming has developed rapidly as a popular movement within world agriculture. The sustainability movement provides an excellent "vehicle" for promoting best management practices. Research in application technology must be cascaded to the growers via interesting methods and, above all, make good business and environmental sense.

Many of the comments made by researchers in the early to mid 1980s regarding engineering controls and protective clothing still exist today, 25 years later. Have we made an impact in protecting the operator?

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