V. WORK PRACTICES

Ideally, pesticides should be manufactured and formulated within enclosed, remotely operated systems to isolate them from workers. However, even with such systems, opportunities for exposure arise. Workers must be protected while the systems are being installed and tested. Systems may break down, causing leaks and demanding the attention of maintenance workers. Periodic cleaning of process equipment and sampling may also call for the opening of closed systems. Fires, floods, and other calamities may cause the breach or destruction of such engineering systems. Consequently, engineering controls alone cannot provide complete protection from worker exposure to pesticides.

The need for a program that includes both engineering and work practice controls is illustrated by the 1976 pesticide overexposure cases in California's manufacturing and formulating plants. Of the 18 cases for which the manner of exposure could be determined, 6 resulted from open operations and could have been prevented by enclosure or ventilation. The other 12 cases involved escape of pesticides during leaks, ruptures, maintenance, sampling, or clean-up operations [297].

An effective work practices program encompasses many elements. For example, monitoring the workplace environment and workers' health can provide data necessary to plan and evaluate control methods. Protective clothing and equipment, if properly selected, used, and maintained, can isolate workers from exposure to pesticide chemicals. Housekeeping, sanitation, and hygiene practices include methods to segregate, collect, and dispose of fugitive pesticide materials to further prevent worker exposure. Provisions for dealing with emergencies are also a necessary part of the work practices program. Work practices are supported by labeling, posting, and training to inform personnel of pesticide hazards and of the procedures that protect against such hazards. Good supervision provides further support by ensuring that the work practices actually do protect workers from exposure.

Monitoring

As described in Chapter III, there is great variety in the toxic effects of pesticides, in the forms in which pesticides are made and handled, and in the operations employed in pesticide manufacture and formulation. Development of an effective program to control worker exposure to pesticides often involves a selection among alternate means of control. For instance, the physical properties and concentrations of airborne pesticides affect the choice of ventilation and enclosure methods. The chemical reactivity and physical form of pesticides indicate what types of personal protective equipment should be selected. The plant layout and movement of pesticides through it determine the type and scheduling of plant housekeeping. The state of health and exposure experience of workers limit their work assignments and the protective equipment they can wear.

Such choices are crucial. A wrong decision can lead to overexposure against which protection was intended. The following examples highlight the need to have adequate information in order to provide correct methods of exposure control for a particular situation. In one case, a production worker was wearing goggles while repairing a pesticide milling machine. His goggles were not dust-tight and both of his eyes were exposed to parathion [297]. In another case, a formulating company using mevinphos issued protective work clothing to its employees, but the clothing was of an improper type for protection against OP pesticides. Seven workers experienced mevinphos poisoning [29]. In another mevinphos incident, a worker with an abnormally low red blood cell (RBC) cholinesterase (ChE) level was assigned to fill cans with mevinphos and he experienced mevinphos poisoning [29]. In the case of a pesticide and fertilizer processing company, materials were stored away from the production area to minimize worker exposure. However, ammonium nitrate (an explosive) was warehoused so near to parathion, dicofol, and other pesticides that its explosion may have spread the pesticides over a wide area. A fire in the plant brought that hazard to the attention of state officials [305]. One pesticide formulator used ventilation as a protective measure in its cylinder-filling area. The company chose to use general ventilation when local exhaust ventilation would have been more appropriate for the packaging operation. As a result, a worker engaged in filling was overexposed to chloropicrin [29]. By monitoring both the pesticide and the worker in terms of their interactions, information is obtained regarding actual and potential worker exposure. The monitoring data can then be used to select and to apply engineering and work practice controls appropriate for each pesticide manufacturing or formulating operation.

(a) Pesticide Monitoring

In the course of manufacture and formulation, pesticide chemicals move through various operations and undergo changes in form and concentration. The nature and quantity of pesticide to which workers may be exposed vary within each plant and from one plant to another. Providing protection attuned to each variation requires monitoring the pesticide in both normal processing operations and in those situations where it escapes from those operations.

(1) Pesticides in Processing

An initial pesticide plant survey should include an inventory of those pesticides present, and the physical, chemical, and toxicological properties of each. Besides aiding management in its selection of protective measures, this information may be required by physicians treating exposed plant workers or firemen fighting plant fires. A common practice is the delivery of an active ingredient to a formulator with specifications for formulation but with no further information on the pesticide itself. The formulator may be ignorant of the composition, properties, and hazards of the pesticide active ingredient [8(p 15)].

The survey of pesticide processing should follow the materials as they move through the plant. Locations and types of equipment within the plant where pesticides are present should be noted so that adequate posting and labeling can be done. The monitoring of pesticides throughout the plant includes surveying pipes, troughs, and conveyors which carry pesticides within the production area. Nonenclosed operations and sources of potential leaks, as discussed in Chapter IV, should be identified to initiate environmental monitoring. Locations of pesticides within the plant layout will also be used to determine emergency escape and rescue routes.

Pesticide plants should be surveyed on a continuing basis. Changes in processing methods, variation in products, and fluctuations in material quantities used and stored all affect the potential for exposure to pesticides.

(2) Pesticide Emissions

The working environment should be monitored to determine the amounts and distribution of pesticides that have escaped into the workplace. This provides a measure of how and where engineering controls have failed to contain pesticides, and also indicates work practices that are necessary to prevent further exposure. Essentially, such monitoring means maintaining a day-to-day awareness of where exposures may occur from emitted pesticides within a plant. Work practice controls dependent on monitoring include selecting respirators and determining where workers can safely eat and drink.

Monitoring may include workplace air and surfaces. Various sampling methods are available for monitoring, but the predominant consideration must be to measure pesticides to which workers are potentially exposed. Airborne pesticides can be sampled by collection devices worn by employees, with the device intake located within the breathing zone, though this may not always be practical. For airborne particulate pesticides, respirator filter pads have been used as sampling devices [306]. Pesticide contamination of surfaces can be sampled with wipe tests [307], using an absorbent material to soak up pesticide from handrails, furniture, etc, or with dermal pads, ie, absorbent swatches worn on the outside of workers' clothing, [306]. For pesticides that are difficult to sample or to analyze, a labeling material may be added for ease of monitoring. Fluorescein dye, for example, has been used to label hazardous materials to study their dissemination [307]. Relatively innocuous materials such as glycerin may be used to simulate the behavior of hazardous substances during their processing.

Environmental monitoring data should be recorded and maintained for use with other monitoring data. The correlation of airborne concentration data with medical examination reports may be very useful in identifying pesticide exposures.

(b) Worker Monitoring

Many work practices are effective in protecting a worker from exposure only when he follows specific behavior patterns in performing his assignment. Selection of specific work practices calls for an analysis of how and where various operations are carried out. Evaluation of whether work practices are being used to afford adequate protection requires an assessment of the employees' state of health. Knowledge of job characteristics and physical capabilities of workers provides a basis for assigning workers to jobs where they would be least vulnerable to the effects of exposure.

(1) Worker Tasks

The object of task monitoring is to determine at what points exposures to pesticide may occur in a given job. If possible, a worker should be rerouted if his assignment requires his passing through a pesticide-contaminated area; in any case, he should always be apprised of the hazard. When a job requires opening pesticide systems to sample or to perform maintenance, the appropriate personal protective equipment must be used. The scheduling of jobs affects time at risk of exposure and may determine whether a worker has time to put on protective equipment before commencing work, or to shower after work. All of these aspects must be monitored to determine work practice controls.

The pesticides with which each worker may have contact must be identified. This determination is important in deciding how the worker is to be trained and what types of medical and biologic tests should be used.

(2) Worker Health

The demands and risks of working in pesticide manufacture and formulation require a level of fitness in workers which should be determined in a preplacement examination, and results should be used by the physician with regard to proper placement of the employee. Such examinations can be used to detect disabilities such as deafness which could impair a worker's ability to protect himself, predisposing conditions such as allergies or pregnancy which could make individuals more susceptible to pesticide effects, illnesses such as cirrhosis or pulmonary disease which could aggravate the effect of pesticide exposure, occupational disease from past exposure to other pesticides, toxicants, or irritants, and cardiopulmonary or psychologic problems which could preclude a worker from using a respirator. The preassignment physical also provides an opportunity to establish the baseline levels of an employee's health before any exposure to pesticides occurs. Baseline levels can be used to compare pre- and post-exposure health aspects such as regularity of menstruation, or to compare specific pre- and post-exposure laboratory testing parameters such as blood ChE activity. In assessing the prospective employee's general health, it is important to be aware of other health aspects that may synergistically amplify the potential adverse effects of contact with pesticides. These include tobacco smoking and the use of alcohol, medications, and other drugs, such as caffeine in coffee.

One other significant but often overlooked purpose of preplacement physicals is counseling employees to be aware of their own states of health. A worker informed of the symptoms and effects of pesticide exposure may discern his own health problems as well as those of coworkers at an earlier stage.

Periodic physical examinations with appropriate biologic testing provide a continuing assessment of employee health and indicate whether a change in job assignment is necessary. Such exams may detect worker exposures by measuring pesticide chemicals or their metabolites, or by identifying the effects of exposure.

Unscheduled exams should also be administered when unusual circumstances arise. Any worker sustaining an illness or injury symptomatic of pesticide poisioning should be examined to determine attributability to pesticide exposure. Conversely, any worker who has been or is suspected of having been overexposed to a pesticide chemical should be examined to determine the effects and need for medical treatment. EPA has published a guide for treatment of overexposure to various classes of pesticides [36].

(A) Medical Monitoring for Level of Exposure

Two levels of screening must be considered in developing standards for medical monitoring: a determination of whether there has been an absorption of unacceptably high quantities of pesticide, and an analysis of any signs and symptoms of pathologic processes resulting from excessive exposure. Selection of monitoring techniques and interpretation of results will vary with the level of screening, the particular pesticide or pesticide class, and the target organ(s) potentially involved.

Environmental monitoring cannot quantify the true hazard where exposure is primarily through skin contact, or where exposure control is dependent on personal protective devices being in place and functioning properly. For those pesticides that carry a high risk of systemic effects, eg, lead compounds, it may be more valuable to monitor workers for absorption of the pesticides rather than to perform extensive tests for the pathologic effects of the pesticides. Such tests for the body burden of a pesticide can give results that are more quantified and more easily comparable to baselines and group results than are clinical tests. Where possible, of course, it is preferable to be aware of both the absorption and the effects. Biologic monitoring has the advantage of usually detecting hazardous exposure levels before clinical effects are evident. A disadvantage of biologic monitoring is that it can miss intermittent overexposure. A biologic monitoring program must include consideration of (1) the availability of analytic techniques for various pesticides, their metabolites, or indices of their biologic effects, (2) the cooperation of the workers in providing samples, ie, the results of the program must not be seen as punitive in nature, and (3) the determination of the concentration of a pesticide or its metabolites in biologic fluids, or the changes in other indices of exposure that identify potentially hazardous exposures. In the absence of medical criteria for pesticide burdens, each worker's level should be compared with the mean level for all the workers monitored and to his mean from previous biologic monitoring periods. The probability of all workers being overexposed and, therefore, each being "acceptably" close to the mean cannot be ignored but must be interpreted by the physicians at their discretion.

In the case of those pesticides for which biologic monitoring is feasible, the scientific literature [308] provides discussion of which body fluids or tissues are most reliably or practically analyzed for the presence of pesticides or their metabolites. In some cases, the higher sensitivity of blood analysis is unnecessary, because acceptable blood levels may produce measurable quantities in the urine. In these instances, urinalysis would be preferred since urine collection is far more acceptable to the employee than is venipuncture.

Although employee exposures should ideally be measured by environmental (workplace air) monitoring, percutaneous exposures which are significant with pesticides may be assessed by biologic monitoring. The choice of biologic tests should avoid invasive tests, eg, blood sampling, when possible, but not at the risk of using a method which is inaccurate or may miss significant exposures, eg, observation of pupillary dialation as an indicator of overexposure to organophosphorus compounds (OP's). In no event should biologic monitoring be depended upon as a substitute for engineering controls and work practices.

(B) Medical Monitoring for Effects of Exposure

A variety of effects of pesticides on humans have been determined from case studies, epidemiologic surveys, and extrapolation of animal data. Each effect involves a target organ for which clinical evaluation criteria have been developed, consisting of symptoms (history), physical examination, and laboratory data. Although a thorough history and a focused physical examination will permit an examining physician to determine the presence of most pathologic processes at some point in their evolution, laboratory studies are necessary for early determination of dysfunction or disease for the organs that are relatively inaccessible and that have a high degree of functional reserve.

In the screening aspect of a medical program, the anticipated worker's acceptability of each recommended laboratory test must be balanced against the test's sensitivity, the seriousness of the abnormality to be detected, and the probability of the abnormality's developing from pesticide exposure. Furthermore, tests are chosen for simplicity of sample collection, processing, and analysis wherever possible. In many instances, tests are used because they are easy to perform and are sensitive, although they are not necessarily specific. If the results are positive, another more specific test would be requested. The choice of tests should be governed by the particular pesticide(s) to which a worker is exposed. A complete medical history and physical exam (including a thorough neurologic exam) are required regardless of the pesticide involved because of the probability of undiscovered effects. Appropriate laboratory tests and elements of the physical examination to be stressed are described in the following paragraphs according to target organ systems.

(i) Skin

Pesticides are known to produce a variety of symptoms related to the skin. The clinical syndrome falls into the two broad categories of dermatitis: contact irritation and sensitivity reactions, as discussed in Chapter III.

Skin sensitization does not occur on the first exposure but may occur after several weeks or many years of pesticide contact [138]. Sensitization may occur after either skin contact or inhalation. Although the process is more likely to occur after prolonged exposure at high concentrations, subsequent allergic responses can result after exposure at very low concentrations. Patch testing can be most useful as a diagnostic aid where a worker who routinely comes into contact with several pesticides has developed symptoms of skin sensitization. However, patch tests used as a preplacement screening technique may cause senitization in the employee. As with contact irritants, skin sensitization potential is best determined by medical history and physical examination.

(ii) Liver

Liver toxicity is a well-documented effect from absorption of chlorinated hydrocarbons and chlorinated organic acids [121,122,124]. Because of the liver's vast reserve functional capacity, only acute hepatotoxicity or severe cumulative chronic damage will produce recognizable symptoms. These include nausea, vomiting, diarrhea, weakness, general malaise, and jaundice.

Numerous blood chemistry analyses are available to screen for early liver dysfunction. The tests most frequently employed in screening for liver disease are serum bilirubin, serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), gamma glutamyl transpeptidase, and isocitric dehydrogenase. Preplacement physical examination, laboratory studies, and a thorough social history are important in order to rule out liver damage from excessive alcohol consumption or other previous conditions.

(iii) Kidney

Impaired renal function can result from chronic exposure to various pesticides, including carbaryl [105], methyl bromide [127], mercury compounds [129], and pentachlorophenol [131]. Screening for kidney dysfunction can be accomplished by measurement of blood urea nitrogen (BUN) and serum creatinine and by urinalysis for presence of protein, glucose, castes, and cells [308].

(iv) Respiratory

Besides providing a route for absorption of pesticides by inhalation, the respiratory system is itself subject to toxic effects from pesticide contact during breathing. Local irritation may occur in the sensitive mucosa of the nose, mouth, throat, trachea, and bronchi. More severe effects include pulmonary fibrosis, emphysema, and bronchopneumonia. Symptoms can be acute, usually resulting from accidental inhalation exposure, although other routes of exposure have been implicated. Paraquat has caused pulmonary fibrosis in humans [150]. Exposure to a copper sulfate-lime pesticide spray caused hystiocytic granulomas and nodular scars [125].

In the absence of acute symptoms, physical examination is not likely to detect early pulmonary fibrosis or asymptomatic emphysema. X-ray examination of the chest and pulmonary function studies (spirometry) are recommended as screening tests for detection of pulmonary fibrosis and emphysema. Baseline (preemployment) studies are imperative for the proper evaluation of changes due to pesticide exposure. Lower respiratory secretions (sputum) may be collected for cytologic examination. Some pesticides have been implicated as being carcinogenic in humans [98,167], especially arsenic compounds which appear to increase the occurrence of respiratory cancer [48]. Sputum cytology has been recommended as a means of detection of pulmonary carcinoma in high-risk groups [82] and is required by the Occupational Safety and Health Administration (OSHA) in its Coke Oven Standard.

(v) Eye

Most eye effects from pesticides are acute chemical injuries resulting from accidental spraying, splashing, or contact with dusts. An important exception is the risk of cataract production from pesticides such as dinitrophenol [51] and dinitro-o-cresol [309]. Screening procedures for cataracts include testing of visual acuity with corrective lenses in place and ophthalmoscopic examination.

(vi) Blood

Both anemia and leukopenia have been associated with pesticide exposure. Reported cases have implicated chlordane [151], lindane [158], and dichlorodiphenyltrichloroethane (DDT) [153]. Anemia may be suspected when there is a history of fatigue with physical findings of pallor and tachycardia, but the definitive screening test is a complete blood count (CBC) which includes determination of hemoglobin concentration, hematocrit, white blood cell count, and white blood cell differential count.

(vii) Heart

Cardiac abnormalities, which have long been associated with arsenic poisoning, have been reported in workers chronically exposed to arsenical pesticides. Changes in the electrocardiogram (ECG) of prolonged Q-T interval and flattened T-waves are associated with arsenic toxicity [310]. Richardson et al [165] reported higher systolic blood pressure among workers exposed to DDT. Exposure of workers over the age of 40 to OP compounds may increase their risk of cardiac failure [163] due to vascular changes and changes in the ability of the blood to coagulate (GE Quinby, MD, written communication, May 1978).

(viii) Reproductive System

Recent findings of infertility in male workers exposed to DBCP have demonstrated the necessity to monitor sperm counts in workers exposed to dibromochloropropane (DBCP) and to other pesticides such as Kepone which have shown effects on reproduction in animals. Studies performed on workers exposed to DBCP demonstrated a correlation between oligospermia and elevated blood levels of follicle stimulating hormone (FSH) and luteinizing hormone (LH) [119].

(ix) Nervous System

The most frequently reported human

health effects of pesticide exposure are those related to the nervous system. Symptoms cover the full range from headaches and tremors to epileptiform convulsions [33]. Behavioral problems attributed to chronic pesticide exposure range from anxiety and depression to hallucinations and schizophrenia [43,44]. Compounds from nearly every pesticide class have been demonstrated to have neurotoxic effects either on the central nervous system (CNS) or on peripheral nerves. Medical monitoring for neurotoxic effects must include a thorough history and neurologic examination.

Acetylcholine transmits nerve impulses to the heart and other cholinergically innervated muscles and other effectors. This kind of transmission is terminated by hydrolysis through ChE's of the acetylcholine released from nerve endings. OP and carbamate pesticides are known inhibitors of ChE's. The inhibiting effect of these pesticides may be measured by determination of ChE activity in the blood plasma and RBC's [97]. Although carbamates inhibit ChE activity, their effect is usually brief and reversible. The duration of ChE depression due to OP pesticide exposure makes periodic monitoring of ChE activity a useful tool to detect occupational exposures [311].

The monitoring requires establishing a baseline for each worker, because normal values may vary greatly from one individual to another. RBC ChE activity should be determined for workers exposed to OP insecticides. Measured values of ChE activity determinations can vary due to when blood is sampled, the laboratory used, and the method employed. Some of the more widely used and accepted methods are Modified Michel, pH Stat, and Ellman (see Appendix II). In addition, some OP and carbamate insecticides preferentially inhibit plasma ChE. Monitoring of plasma ChE activity should be considered by the physician for those employees exposed to such OP insecticides [311].

Several researchers have suggested that electromyography and electroneurography may have use as indicators of functional myoneural disturbances in the absence of depressed ChE activity [32,33,43,115,116].

(C) Frequency of Medical Monitoring

Medical exams and biologic tests must be administered frequently enough to detect occupational illness, ideally before the exposures induce any deterioration of health. However, several factors limit frequency of monitoring. Expense to employers and acceptability to employees are significant administrative considerations. From a health standpoint, some tests and examination methods pose a health hazard which must be weighed against the exposure hazard being screened. Drawing blood can carry some health risk, and X-ray examination exposes workers to radiation.

It is common practice to decrease the interval between physical exams with increasing worker age. One major manufacturer of pesticides gives mandatory physicals to workers less than 45 years of age every 1.5 years, and annually to workers over 45 years of age [312]. A large formulator of pesticides requires exams at ages 25, 30, 35, 38, 40, and annually thereafter [313].

Besides employee age, job assignment may determine how frequently total physical examinations or particular biologic tests are given. Workers in high-risk occupations such as pesticide packaging should be examined at least annually. Employees who work with OP pesticides may require blood ChE tests as often as weekly [297].

Recent studies have indicated several alternatives in selecting the frequency of medical monitoring. One plan would require very infrequent mandatory exams (every 5 years), with exams offered voluntarily every year. Another alternative proposes 2- to 5-year intervals for asymptomatic workers, with exams being given whenever a worker believes he has been exposed. This, of course, requires training workers to recognize signs and symptoms of pesticide intoxication.

The frequency of biologic testing and periodic exams should be related to the period of time in which the pesticide could cause adverse effects as well as the severity of the effects.

Personal Protective Clothing and Equipment

In 1975, there were 94 reported cases of occupational illness resulting from exposure to pesticides or their residues in manufacturing and formulating facilities in California. Exposed were 54 production workers and 40 workers who were cleaning or repairing pesticide-handling equipment. Exposures were due to inhalation, ingestion, and skin or eye contact with the pesticide chemicals [29]. Where engineering controls, as discussed in Chapter IV, are inadequate or infeasible, other methods of protection must be used. Use of personal protective equipment and clothing provides another means for reducing occupational exposures by isolating the worker from the pesticide. However, it must be emphasized that the use of personal protective clothing and equipment will not by itself prevent pesticide poisoning and should not give the worker a false sense of security. Various types of protective equipment and clothing are discussed below.

(a) Protective Clothing

In the manufacture and formulation of pesticides, many opportunities can arise for unintentional direct contact of the pesticide with the worker. Liquids can be splashed or spilled onto the worker's skin or into his eyes. Dusts may be blown into the worker's eyes or mouth. Engineering controls alone are not always sufficient to prevent these occurrences. Therefore, direct protection of the routes of entry by use of protective clothing should help reduce these exposures. In an incident describing the effectiveness of protective clothing, a worker who was filling and capping drums of mevinphos had some of the chemical splashed on his arm [29]. Because he was wearing protective clothing at the time, he had very little skin exposure and only experienced mild symptoms of overexposure. Violations cited by OSHA in pesticide plants have included lack of proper protective clothing; workers involved in pesticide manufacture and formulation have risked exposure to parathion, chlordane, and dichlorvos because of inadequate protective clothing and equipment.

Wolfe and Armstrong [18] studied the effectiveness of personal protective equipment in two DDT formulation plants. Calculations were made to estimate the maximum potential exposure that could occur in different work situations where protective gear was not used. Potential exposure was calculated assuming that a worker wore an open-collar sleeveless shirt, no respirator, no hat, and no gloves. These exposure values were compared with the actual values obtained, taking into account the protective clothing and respirators actually worn by the workers. Workers in both formulating plants wore rubber boots, caps, respirators, long-sleeved cloth coveralls open at the neck, and rubber gauntlet gloves, which provided some protection at the wrist area not covered by the sleeve. In plant A, the caps worn were the type with a bill at the front. The bill was considered to give some protection from downward-moving particles in the face-front area, but very little protection on other face-neck areas. In plant B, the caps worn were beanie-type with no bill and provided protection only for the top of the head. Rubber aprons were worn in plant B, and that plant also had better ventilation and other engineering controls. Exposure values were calculated for each worker, taking into account the estimated percentage of skin area actually exposed. By comparing the mean values of toxic dose received per hour with those calculated for the theoretical "minimum protection" exposure, it was calculated that had the workers not worn their protective equipment they would have been exposed to 5-10 times more DDT in plant A and approximately 2.5-3.5 times more DDT in plant B.

Protective clothing ranges from gloves and aprons to garments that completely cover the body. There is also a diversity of materials used in these clothes including rubber, leather, cloth, and synthetic fibers. Because of the many types of clothing and material available, selection of proper protection should be carefully considered. Probably the most important criterion for selection is the degree of protection which a particular piece of equipment affords against a potential hazard. This should take into account the physical form of the pesticide chemical, ie, solid, liquid, or gas. For liquid formulations, or wet hygroscopic solids, this is particularly important, because of the possibility of permeation through the clothing worn. Although cloth coveralls provide a reasonable amount of dermal protection, the wearing of waterproof trousers provides the best protection for the lower trunk and leg areas and is especially recommended in work situations where there is a chance of liquid spillage or penetration due to excessive contact with dry pesticides. For gases such as methyl bromide, the use of gloves may cause the volatile gas to be trapped next to the skin surface and thereby increase absorption (J Conder, written communication, February 1978).

To be effective, protective clothing must be impervious to the chemicals it is protecting against. However, impervious clothing may interfere with the body's cooling mechanism by excluding airflow to the skin surface. The effects of different types and weaves of cloth vs their effect in minimizing the penetration of residues contacted in the field has been examined.

Six orange pickers participated in the study wearing 2- x 3-inch patches of tightly woven cotton shirting fabric. The patch was backed up by aluminum foil in order to trap the residues which penetrated. The results of this initial study indicated that 47% of the applied dose of parathion and its more toxic oxidation product, paraoxon, penetrated the tightly woven cotton material. The California State Department of Health recommended the use of nonwoven laminar treated clothing with treatment on both sides of spun-bonded polypropylene. The advantages of this material are that it is lightweight, disposable, and cool to wear in hot weather [314].

Davies [315] reported a study in which silicone was used to treat the clothing of pesticide workers. Shirts, pants, socks, and shoes were dipped in a silicone solution. By measuring metabolites in the urine, it was determined that workers with treated clothing sustained less skin exposure to parathion than those with untreated clothing.

Although protective clothing should be selected for its resistance to chemical penetration, truly impermeable clothing may be difficult to find. In testing various protective glove materials for permeability, Sansone and Tewari [316,317] found that penetration of all materials used occurred with all pesticides tested. Carbon tetrachloride, methylene chloride, tetrachloroethane, trichloroethane, and perchloroethylene substantially (10% or more) penetrated natural rubber, neoprene, and polyvinyl chloride (PVC) glove materials within half an hour. Polyvinyl alcohol (PVA) glove material showed much greater resistance to chlorinated pesticides, but it was penetrated by DBCP and EDB, as were the other materials, in as little as 5 minutes. Only acrylonitrile failed to penetrate each material in 5 minutes, but penetrated all three materials within 30 minutes.

Even when wearing protective clothing, care must be taken to prevent gross contamination from excessive amounts of chemicals. A worker manifested signs of mevinphos poisoning after he leaned against a spout that was used to fill containers with that pesticide. Some of the liquid soaked through his protective coveralls [29]. An OSHA inspection of one pesticide formulator revealed contamination of personal protective clothing by baygon and by sodium arsenite.

Protective clothing should not be worn home or taken home to be laundered. Cleaning should be done at work with appropriate safeguards, or by a professional laundry. This prevents workers from carrying residual chemicals home on their clothing and thereby possibly exposing their families. Despite washing, pesticide chemicals may remain on clothing. Southwick [318] reported one fatality attributable to work clothing that remained contaminated with parathion even after laundering.

Urry et al [319] compared the effectiveness of a common chlorine bleach solution in the removal of pesticides from two fabrics at two different soak periods. The pesticides used were parathion, diazinon, lindane, and carbofuran. The two fabrics, typical of work clothing, were 100% cotton denim and 50/50% polyester/cotton. The stock bleach solution was 5.25% sodium hypochlorite laundering bleach, diluted with water for a final chlorine concentration of 0.05%. Each of the 4 pesticides was applied to the fabrics and each fabric was subjected to the bleach solution for 1 or 24 hours, respectively, for a total of 16 experiments. In denim fabric, after a 1-hour soak, 41.4% parathion, 49.6% diazinon, 21.2% lindane, and 32.5% carbofuran were removed, and after 24 hours, 98.8% parathion, 93.6% diazinon, 14.8% lindane, and 95.0% carbofuran were removed. In polyester cotton, after 1-hour soaks, 41.2% parathion, 60.9% diazinon, 19.0% lindane, and 72.5% carbofuran were removed; and after 24 hours, 96.4% parathion, 98.6% diazinon, 17.1% lindane, and 100% carbofuran were removed. The authors concluded that a 1-hour soak in 1% chlorine bleach alone was not sufficient to remove some types of pesticide contamination; however, after a 24-hour soak, removal was quite good, except for lindane. They suggested that combinations of bleaching and soap laudering would be more effective in pesticide removal than using bleach alone.

Protective clothing should be kept separate from street clothing so that contamination of street clothing will not occur. The clothing should be inspected frequently for rips or tears and repaired or replaced when so indicated.

(b) Gloves and Gauntlets

Dermatitis and absorption of chemicals through the skin are two main problems associated with the handling of pesticides. Gloves and gauntlets are specialized types of protective clothing designed to protect the hands and forearms from contact with pesticide chemicals, thereby reducing exposure of the skin.

Handling pesticide chemicals or their containers with gloves reduces exposure to leaked pesticides, especially those which may penetrate the skin. A foreman taking a sample accidentally popped a lid on a vial and spilled mevinphos on his hands [29]. Even though he washed immediately, he still developed stomach cramps. Another worker was hospitalized for 3 days and was treated for OP poisoning after using his bare hands to put the cap back on a mevinphos sample container [29]. In both of these cases, gloves were provided and required for taking the sample but had not been worn. One employee developed dermatitis on her hands and forearms after filling bottles with malathion [29]. She had refused to wear rubber gloves that were provided.

Gloves should be checked before each use to ensure that they are not damaged or contaminated on their inside surfaces. A batch maker in a formulation plant, who was wearing gloves, spilled a fungicide on his hands and developed contact dermatitis [297]. The accident report surmised that either the gloves had a hole in them or some of the chemical spilled into the top of the gloves. Inspection of the gloves might have prevented the exposure.

(c) Foot Protection

Protection of feet requires specialized types of protective clothing in the form of shoe coverings or boots. This is especially important where liquid pesticide chemicals are handled. First and second degree chemical burns were sustained by a production operator who was not wearing any foot protection when he spilled ethylene dibromide on his foot [297]. Wearing rubber boots might have prevented this accident.

If foot protective devices become contaminated, they should be decontaminated or replaced. A foreman who spilled ethylene dibromide into his boot washed his foot and then put the contaminated boot back on [320]. Chemical burns and dermatitis of his feet resulted.

Boots and other foot coverings need to be examined on a regular basis for any holes or breaks that would permit leakage of pesticide chemicals. When not in use, protective footwear should be stored in areas free from contamination.

(d) Head and Face Protection

Many different types of protective equipment are available for preventing exposures of the face and head to pesticide chemicals. These include safety glasses, goggles, face shields, and various types of hats.

Protection of face and head is important, considering the different sites and routes of exposure to pesticides. According to one study [20], the human body absorbs parathion at rates that vary from 32% for the scalp to 47% for the ear canal, to an estimated 100% for the eyes (see Table III-1). During 1975 in California, 8 out of 56 (14%) production workers and 15 out of 40 (38%) maintenance men who experienced occupational illnesses due to pesticides received eye exposures [321].

Head protection is important where exposure from overhead sources is likely to occur. A helmet with a brim all the way around provides the most complete protection for head, face, and back of the neck. Protective caps which completely cover the hair are necessary for two reasons. First, they prevent exposure of the scalp, and second, they keep pesticides from being retained by the hair and later falling into the eyes, or acting as a continuous source of dermal exposure. Headgear should be cool and lightweight so that it is comfortable for those wearing it.

Each job should be evaluated for the possible exposures that could occur and protective equipment chosen accordingly. If there is a danger of liquids being splashed into the face, a face shield should be worn. Splash-proof goggles will prevent liquids or dusts from getting in the eyes.

Care must be taken in selecting protective equipment lest it provide a false sense of security. Workers wearing inadequate equipment might not realize that they are being exposed if they think they are wearing the proper equipment. Maddy and Topper [29] cited two cases where workers were wearing safety glasses instead of goggles, and eye injury occurred. In another case, a worker had captafol powder blown into both his eyes through the side vent of his goggles. In each of these cases, exposure could have been prevented by better job evaluation and selection of appropriate equipment. One employee had liquid lime sulfur splashed into his face [29]. Although the use of safety equipment was not required by the employer for the job he was performing, a face shield might have guarded against such exposure.

Maddy and Edmiston [297] cited two cases where eye contamination occurred because no protective equipment was worn.

In one case, a supervisor had "ant powder" blown into his eyes while trying to repair a packaging machine. In another instance, a can of insect spray exploded and sprayed pesticide into the eyes of the machine operator.

When selecting protective equipment for the face and head, different configurations and construction materials are important factors. Plastic lenses are more resistant to breakage and hot materials, and take longer to fog than most glass. Plastic also weighs less, which aids in wearing comfort. If equipment is not comfortable, workers will resist wearing it. One worker had propargite sprayed into his eyes after he removed his goggles [321]. It was a hot day and the goggles irritated the skin around his eyes.

If a worker needs corrective lenses, it is preferable to grind the correction into a goggles lens [322]. Where this is not possible, special goggles that fit over glasses are required. Although considerable controversy exists regarding the wearing of contact lenses during chemical exposure, contact lenses should not be worn because of the possibility of getting contaminants, particularly liquids and vapors, caught between the contact lens and the eye, which may result in severe chemical burns. However, if goggles containing corrective lenses substantially reduce the employee's vision, contact lenses may be worn under splash-proof chemical goggles.

Face shields, which attach to head gear, are designed to give protection to the entire face from the forehead to the neck. They are used mainly where splashing of liquid pesticide chemicals is likely to occur.

When not in use, protective equipment should be stored in areas free from pesticide chemical contamination. If equipment were left in a place where it became contaminated, it could become a source of exposure for the next user. Before using protective equipment, each worker should ensure that it is clean and that is has not been damaged in any way that would prevent proper functioning.

(e) Respiratory Protective Equipment

Cases of occupational illness and death have been attributed to lack or improper handling of respirators and to improper guidance as to respirator use in pesticide facilities. De Palma [113] reported three cases of exposure to arsine due to nonuse of respirators in a plant producing the herbicide sodium acid methane arsenate.

Kazantis et al [106] cited another incident in which respirators were not used and overexposure occurred during the mixing of aldrin with fuller's earth. The employee's exposure might have been reduced by engineering controls, but in the absence of such controls, a much more effective type of respirator should have been used.

In the above-mentioned incidents, proper assessment of the hazard could have led to providing appropriate protection to the workers. Hazard control, as previously mentioned in Chapter IV, should start at the process, equipment, and plant design levels to control contaminants at their source.

(1) Respirator Selection and Limitations

Respiratory protection devices vary in design, application, and protective capability. The user, supervisor, and employer must therefore assess the inhalation hazard and understand the specific use and limitations of available equipment to assure proper selection.

Respiratory protective devices are tested and approved by NIOSH and the Mining Safety and Health Administration (MSHA) for protection against a wide range of inhalation hazards, including oxygen-deficient and highly toxic atmospheres and those containing "nuisance" dusts. Whenever possible, it is desirable to select NIOSH/MSHA-approved equipment. Testing and approval of these respirators are subject to conditions in 30 CFR Part 11.

In addition, 29 CFR 1910.134 states that respirators shall be selected on the basis of the hazards to which workers are exposed and that ANSI Z88.2-1969 shall be used for guidance in this selection. Many of the criteria for selection of respirators, including the joint NIOSH/OSHA decision logic for respirators [323], are dependent on permissible exposure limits and therefore cannot be applied to substances for which Federal standards have not been established. Both the ANSI standard and the NIOSH/OSHA decision logic use other criteria in addition to exposure limits for deciding respirator use, including the possibility of skin absorption, poor warning properties, and eye irritation by the material. The following are guidelines suggested in these criteria [323]:

(A) Supplied air suits provide both skin and respiratory protection and should be used in handling extremely toxic substances which may be absorbed through the skin.

(B) Only full facepiece respirators should be used when contaminants may produce eye irritation.

(C) For firefighting, the positive pressure, self-contained breathing apparatus should be used.

In some industry segments [8(p 82)], chemical cartridge and canister masks are not used and positive-pressure air supplied respirators are preferred. Two types of the latter are available: self-contained breathing apparatus and air-line respirators. These air-supplied respirators can be safer than chemical cartridge or canister mask respirators. When the positive-pressure type of air-supplied respirator is worn, facepiece leaks will simply allow air to pass out of the facepiece rather than into it. The worker is not dependent on the surrounding air which may be a source of a pesticide or other contaminant, thus further decreasing chances for exposure. If there is an oxygen-deficient atmosphere, such as may occur in a reaction vessel, only self-contained equipment should be used [324].

The protection afforded by any respiratory device is limited by the quality of the seal between the respirator facepiece and the wearer's face. Facial seal, and therefore, respiratory fit, can vary due to a variety of factors, such as the facial contour, the way the respirator is donned each time it is used, the amount of perspiration on the face, the amount of beard growth, the tightness of the straps, and other factors. A study in 1973 [325] indicated that both daily growth of facial hair as well as established beards detrimentally affect the seal of respirators.

The use of eye glasses also affects the facial seal of respirators, and wherever glasses penetrate the seal, a leak and resultant loss of protection will occur. Various ways of preventing this leakage have been utilized, including mounting the glasses inside the facepiece. The use of contact lenses is not a good solution to this problem. If a contact lens should happen to slip or need adjustment while the respirator facepiece is being worn in a hazardous atmosphere, a serious problem would exist since removal of the respirator would not be possible and immediate escape from the atmosphere may not be possible either.

A limitation of air-purifying respirators is that the end of service life for a cartridge or canister is not always evident. In formulating and manufacturing areas, inherent problems arise when odor detection is used as a sign of exposure because some contaminants do not have detectable odors. Also, the odor threshold may be higher than an established permissible exposure limit, or the odor of the contaminant may be masked by other airborne substances.

Another major limiting factor in wearing respirators is the breathing resistance inherent in many respirators, such as the canister type. Respirators approved under 30 CFR Part 11 have inhalation resistances varying from 12 to 102 mm of water and exhalation resistances varying from 15 to 25 mm of water; these respirator performance specifications are for normal, healthy men

[325]. Pulmonary disease, the resistance to airflow in respirators, and pulmonary function capability of "normal" healthy workers must be considered in evaluating whether employees can use respirators. In the case of self-contained breathing apparatus, weight of the equipment would also be a factor making the respirator difficult to use. If a worker's cardiovascular or pulmonary function is impaired, wearing a respirator may constitute an unacceptable risk due to breathing resistance and/or weight of the respirator apparatus itself. Also for all Group I pesticides, where respirators are necessary, a quantitative fit test should be performed to ensure that the employee is not exposed to pesticides as a result of substantial leaks.

(2) Respiratory Protective Equipment Care

If respirators are to be effective, they must have proper care. In one NIOSH site visit of a formulating plant [8(p 75)], respirators were sometimes dirty or lying on workbenches. This may lead to contaminated filters, cartridges, or facepieces, and potentially allow for direct inhalation of a pesticide. Certain respirator parts must also be handled carefully. Rubber facepieces become hardened and head straps lose their elasticity with age and exposure to heat and sunlight. These conditions lead to poor fit and allow leakage around the facepiece. Because the respirator may be used as a life-protecting system, the necessity for its proper maintenance must be emphasized to workers in respirator use training. Several pesticide formulators have been cited by OSHA for failure to have a comprehensive program covering respirator use and maintenance. Such practices have potentially exposed workers to chlordane, Kepone, and phorate.

Two of the more common bad practices reported [327] are: (1) failing to wash the facepiece properly and (2) neglecting to change the filter cartridges or canisters regularly. Washing of the facepiece of a cartridge-type respirator should not be attempted while the cartridges are in place since moisture may contact the activated charcoal filter material. Merkle, at the National Conference on Protective Clothing and Safety Equipment for Pesticide Workers [328], suggested a procedure for cleaning respirators. The mask parts (with filters removed) and other protective gear should be placed in a 5% solution of sodium hydroxide or a strong alkaline soap solution for a minute or two, followed by a thorough rinse with clean water. Cleaning of the mask parts with a cleaner-sanitizer, such as ethanol, was also recommended. Solvent materials that affect rubber should never be used as cleaners because they may cause deterioration of rubber parts.

Proper maintenance and storage of respirators are also essential to a respirator's continuing effectiveness. Merkle [328] recommended that in the specific case of maintaining methyl bromide respirators, gas mask canisters should be replaced after each use because methyl bromide has poor retention characteristics in activated charcoal. After a few day's storage, a partially used canister will evolve methyl bromide even when clean air is passed through it and thus will become a potential hazard in itself.

OSHA requires in 29 CFR 1910.134 that respirators be stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, and damaging chemicals. In order to accomplish these objectives, the National Safety Council (NSC) has recommended [322] that freshly cleaned respirators be placed in heat-sealed or reusable plastic bags until reissue. They should be stored in a clean, dry location away from sunlight to protect against loss of elasticity. Storing a respirator in the position in which it is used also prevents distortion of the facepiece, which may cause a poor fit.

(3) Respirator Education

For safe and effective use of any respiratory protective device, the user should be properly instructed in its selection, use, and maintenance. Misuse can be avoided by establishing written procedures for respirator selection and use, and by properly supervising all aspects of a respirator program. The written procedures should contain all information needed to ensure proper respiratory protection of a specific group of workers against a specific hazard or several particular hazards. Description of the limitation of each device against different materials or concentrations helps the user select the proper respiratory protection. The proper use of respirators is highly dependent on thorough assessment of the hazard; otherwise the procedures will have only limited validity.

Another major element to be included in written procedures should be a detailed description for training workers in proper use of the respirator, including fitting. Merkle [328] recommended that each worker have the capability to check for tightness before entering the exposure area. This can only be achieved by training the worker on how to properly wear respirators. Written procedures for cleaning and disinfecting respirators, repair of worn or defective parts, and proper storage instructions aid in reducing exposures.

Particularly important is establishing procedures for respirator use during emergencies such as fire, large spillage of volatile material, accidental release of a toxic substance, or failure of a ventilation system. Confusion that might occur in emergency situations may be alleviated by practice drills. Furthermore, these emergency procedures should be used in training emergency response teams. Location of respiratory devices in these situations is vital for safety of the worker.

Administrative procedures are also important in developing a respirator program. Control of inventory of spare parts, shelf-life information, and notation of dates for servicing ensure proper maintenance of respirators.

Proper issuance of respirators to ensure use of the proper one for a given hazard is another administrative task. Supervisory personnel should be given guidance in surveillance of respirator use and determination of worker's exposures to respiratory hazards. Simply having written procedures is not sufficient. Safety can be firmly established only by supervision to make sure that the proper respirator is being used and by periodic inspection and testing of respirators.

Housekeeping, Hygiene, and Sanitation

Cleanliness of the workplace and personal hygiene is essential to minimizing pesticide exposures. Pesticide accumulations in the working area can expose workers by skin contact when touching contaminated handrails, tools, equipment controls, and furniture, or by inhalation when moving air or vibrating surfaces cause reemission of pesticides into the air. Failure to cleanse pesticides from the skin may not only give rise to dermatitis but also may allow absorption through the skin to cause systemic effects. Contamination of foods, beverages, eating and drinking utensils, or smoking materials allows pesticides to enter the body by ingestion or inhalation.

Lack of cleanliness has been responsible for a variety of pesticide exposures. In one case, the outside surface of pesticide plant equipment was contaminated with a wet mevinphos residue. After contact with the dirty surface, the material soaked through to an employee's skin and he experienced OP poisoning symptoms [29]. Another pesticide exposure was attributed to contact with a worker's contaminated skin surface when a laboratory worker injured his eyes after rubbing them with his dichloropropane-contaminated hands [297]. In another case, the contamination of a drinking container with paraquat led to a fatal overexposure by ingestion [299].

(a) Plant Housekeeping and Disposal

The object of housekeeping in a pesticide manufacturing or formulating plant is to protect employees from pesticide exposure; one way is to recapture spilled or leaked pesticides. This has a direct bearing on cleaning procedures. Flushing contaminated areas with a jet of steam, air, or water may serve only to further disperse the pesticide. For example, a worker accidentally contaminated his eyes with pesticide while using steam to clean pesticide-handling equipment [29]. Another worker, using a high-pressure air hose to flush pesticide, blew the material into his own face causing chemical dermatitis [29]. Surfaces should be washed down only if the runoff can be collected by drains or sumps and can be adequately decontaminated before disposal. Liquid pesticides can be cleaned up by covering with an absorbent such as clay. It is common practice among formulators to reuse the pesticide-soaked absorbent in making formulations [8(p 38)]. Solid pesticides should be cleaned up by vacuuming, but care must be taken that the vacuum system collector entrains respirable particles. Containers of collected waste pesticide should be handled and labeled with the same precautions given to pesticide products.

Pesticide contamination of working areas should be cleaned up as soon as possible. Allowing accumulations increases the risk of worker exposure. In the manufacture of Kepone, 76 production employees out of a work force of 113 experienced effects of pesticide exposure due mainly to gross contamination of the workplace. Kepone covered most of the plant equipment and work surfaces, in some places (notably in packaging operations) to a depth of 2 feet [84]. The method of cleaning is as important as the frequency to prevent worker exposures. Proper personal protective equipment must be worn by workers during cleaning. A pesticide formulating worker was cleaning plant apparatus after removing his protective equipment and was overexposed to parathion [320].

Disposal of pesticide wastes also can cause exposures. A pesticide manufacturing worker sustained organophosphate poisoning while dumping waste [74]. The disposal of spills and toxic wastes into the general sewage system can create problems due to the mixing of materials such as acids, caustics, phosphorus, arsenic, and cyanide compounds which may interact to release toxic gases into the workplace. The disastrous results, including contamination of fisheries and recreation areas and subsequent multimillion dollar lawsuits, that arose from spillage of Kepone into the James River demonstrate other problems that such dumping can create [84].

EPA has established regulations defining prohibited procedures pertinent to the disposal of surplus containers and pesticides (Federal Register 39:36867, October 15, 1974). Specifically, open dumping is prohibited as is open burning, except for small quantities of combustible containers not exceeding 50 pounds or the quantity emptied in a single workday, whichever is less. Water dumping is generally prohibited. Local, state, and Federal regulations should be consulted whenever disposal occurs. Among the suggested precautions are incineration and burial in a manner not detrimental to the air or water environments.

(b) Personal Hygiene and Sanitation

Habits of personal cleanliness can play a significant role in protecting pesticide workers from exposure. Each worker must keep not only his body, but also any object which comes into contact with his body, free from pesticide contamination. The hands should be washed before eating or smoking so that materials entering the mouth do not carry pesticides into the body by ingestion or by inhalation. It is especially important to wash the hands before going to the toilet. Hands soiled with parathion absorbed the pesticide at only a 12% rate, compared with the scrotum which absorbed the pesticide at a 100% rate [20].

Washing methods and facilities must be planned to avoid recontamination or exposure. Faucets for handwashing should be operable by a device, such as a foot treadle, that does not require hand contact. Soap should be dispensed on a per use basis, rather than in a reusable bar form. Abrasive materials which remove layers of skin, or strong alkalies or solvents which defat the skin, should not be used. Individual-use towels should be provided for drying the hands. Even with a carefully selected cleaning material, frequent washing tends to make skin more vulnerable to penetration by pesticides. For that reason, a cream to counteract defatting of the skin should be available. Mirrors should be located over washbasins to facilitate washing the face and neck. The face can absorb parathion, for example, at three times the rate of the hands [20]. A study of body surface exposures to carbaryl among formulation workers showed that the face and neck receive an exposure at least as great as that of the hands [18].

Showering can be somewhat effective in removing pesticide residues from the body surface. Sansone et al [307] conducted a simulation study to assess the effectiveness of various work practices in controlling exposure in materials handling operations. Showering with soap and water removed a substantial amount of skin contamination, leaving some residue on the face. Residues in the towels indicated some removal during toweling of the body. To accommodate worker showering, pesticide plants should be equipped with locker and shower rooms laid out so that workers exit from dirty to clean areas. Workers at Life Science Products failed to shower at the end of the workshift, aggravating their exposure to Kepone and other materials. Their shower facilities were uncomfortable to use, so the workers avoided showering there after work, and 76 of the 113 workers contracted dermatitis [84]. Showers should be located in a sheltered area with a disrobing room on one side for removing contaminated work clothing and with a separate, clean dressing room on the other side so that clean workers do not recontaminate themselves or their street clothing.

Materials that contact the body should be kept as scrupulously clean as the body itself. This practice is best performed by keeping all materials and activities involving eating, drinking, or smoking out of pesticide handling areas. Both lunchroom and smoking areas should be separated--located in another building, if possible--from pesticide manufacturing and formulating operations. OSHA has cited at least one pesticide manufacturer for allowing employees to eat in a pesticide production area. Cigarettes and other forms of tobacco, food, cough drops, chewing gum, or drink should not be carried by workers to their job locations. Clean areas to store such materials away from pesticide production should be available. Food and beverage utensils or containers should never be used in pesticide handling. This practice was not followed by a company which allowed a packing shed to be used as a rest/break area. An employee who mistook aldicarb granules in the shed for coffee creamer was poisoned by his contaminated coffee [74].

Emergency Procedures

Sudden, unexpected calamities within pesticide manufacturing and formulating operations can greatly increase exposure risks. When fires, explosions, collisions and other accidents, or natural forces such as floods, storms, and earthquakes, damage pesticide equipment or containers, the two immediate problems are protecting workers from exposure and treating workers who have been exposed. These problems are usually aggravated in emergencies because of the gross amounts of pesticide that can escape and the limited amount of time in which to deal with them.

In a fire that occurred in a pesticide packaging plant in Tulare County, California [305], firemen and local residents were threatened with pesticide exposure. The fire destroyed containers, releasing large quantities of pesticide chemicals.

Another incident involved the wreck of a tank truck containing 1,3-dichloropropene. The spilled liquid released large amounts of vapor which overexposed 11 firemen on the scene [74].

The importance of time was demonstrated in one fatality due to pesticide poisoning. After accidental ingestion of an unknown liquid formulation, no antidote could be administered because the pesticide was not immediately identifiable [329]. Blood ChE tests were normal, so acetylcholinesterase (AChE) inhibition was not suspected as the mechanism of intoxication. However, it was later determined that the chemical was a carbamate insecticide which depresses AChE activity, and which has a reversible effect on blood ChE. A more timely indentification of the pesticide would have indicated the proper treatment and possibly prevented this death.

Many times, lack of prompt action or incorrect treatment will increase the seriousness of an exposure. In OP poisonings, the errors most often made have included: failure to recognize the potential seriousness of a poisoning and consequent failure to keep the victim under close observation for at least 24 hours, failure to identify accurately the chemical to which the patient was exposed, failure to decontaminate the victim's skin adequately, failure to give adequate amounts of atropine and/or pralidoxime chloride (2-PAM) when indicated, and failure to carry out a confirming blood ChE determination [329].

In any emergency situation, a warning system is necessary to inform employees of hazardous work conditions. Warning systems include fire alarms, devices to detect excessive airborne contamination, devices on equipment to warn of hazardous temperature and pressure extremes, and alarms to warn employees of dangerous spills. Each employee should be trained to recognize alarms and to know what to do when a warning is sounded.

Protective equipment for use in escaping from hazardous areas should be located inside areas where emergencies may occur and should be convenient to employees who may have to use it. Escape equipment should include a respirator, ideally with full-face protection. The respirator must provide workers with adequate oxygen so they will not lose consciousness or breathe hazardous fumes before they can get out of the area. Face protection is necessary to avoid eye irritation, so workers can see to get out of the area. Escape equipment is intended for escape use only; it is not adequate for extended protection or rescue work. Only designated workers should be allowed to remain in or to reenter hazardous areas for purposes of shutting down equipment, for containing or cleaning up spills or, most importantly, for rescuing workers who may still be inside. For these situations, rescue equipment should be available that provides more complete protection than escape equipment. Full body covering and air-supplied respiratory protective devices should be used. Protective body covering must be carefully selected. A firefighter was overexposed to methyl bromide even though he wore a respirator and complete protective clothing. The fumigant was able to penetrate the asbestos fabric in his protective suit [74]. In another incident, the need for a self-contained breathing apparatus was demonstrated in an incident of fire involving methomyl. Heat from the fire caused large amounts of the toxic carbamate pesticide to vaporize. Firemen not wearing the apparatus were poisoned [74].

As mentioned earlier, many dermal and eye exposures can occur in pesticide manufacture and formulation. Because of this, showers and eyewashes are necessary in areas where these exposures might occur. Emergency facilities should be conveniently located so that they may be quickly and easily reached. Pathways to eyewashes should be kept clear of any hazards or obstructions to a blinded worker. For example, a pair of rubber gloves were observed lying in an eyewash fountain during a NIOSH site visit [8(p 92)]. These facilities also need to be checked frequently to make sure that pipes are not frozen or clogged and that there is no pesticide contamination which could worsen exposure.

There should be at least one person trained in first aid present during each shift. This person can take care of injured employees until help arrives or until the employee can be taken to a doctor. Only trained personnel should use resuscitation equipment or give antidotes.

Although fires, explosions, leaks, and spills are the most frequent types of emergency situations, other types of emergencies are possible. Earthquakes are a very real danger in California. One company's safety manual [330] gives specific instructions on what to do in the event of an earthquake. Power failures could be dangerous if they cause equipment to shut down suddenly. Also, the possibility of a natural disaster such as a tornado, hurricane, or flood may exist. Companies should consider the various risks associated with their geographic area and climate, and plan for emergencies accordingly.

Maintenance

Equipment failures in pesticide manufacturing or formulating plants frequently cause pesticide emissions. If employees are in the vicinity of the equipment when it fails or if they must enter the contaminated area to repair the faulty equipment, the emissions can result in exposures. During 1975, California reported that pesticide exposures due to equipment failure were second only to exposures caused during the transfer of materials [29]. The number of occurrences of this type of exposure can be reduced by decreasing the number of equipment failures through an effective inspection and maintenance program [29].

The importance of inspection in pesticide manufacturing and formulating plants is typified by the following example. An employee was exposed to mevinphos when it spilled on his face and eyes from a rusted can which had developed a leak. The author noted that if the company and the employee had kept a careful watch on the condition of the containers this incident might not have occurred [29]. Several pesticide manufacturers and formulators have recognized the importance of this by including inspection procedures in their operations or safety manuals [331].

The inspection of process equipment and control equipment such as ventilation systems can be very important. In plants where total containment is used as an engineering control so that employees need not habitually wear personal protective equipment, the failure of process equipment or the ventilation system can seriously increase the probable occurrence of exposures. Frequently, equipment which is near failure or is in disrepair will not perform its function in the normal manner. Regular inspections can detect abnormal conditions so that maintenance can then be performed.

Carefully kept records of inspections and maintenance (both preventive and regular) can assist plant management in two ways. Records of equipment installation, maintenance, and failure can assist plant management in setting up inspection and preventive maintenance schedules. If equipment is inspected, replaced, or repaired before failure is likely, the risk of exposures occurring can be reduced. The company can benefit from a schedule of preventive maintenance through reduced downtime. Preventive maintenance can be scheduled for many pieces of equipment at one time. Records of equipment failure can be used by plant management to make decisions about which types or brands of equipment operate safely for the longest time.

Operating or safety manuals of pesticide manufacturing and formulating companies often contain procedures for performing maintenance [331], including procedures for precleaning, "lock out," and the "buddy" system. Numerous examples where proper procedures were not followed and resulted in exposures are reported in the literature [29,113,297].

Maddy and Topper [29] suggested that mechanical cleaning be used whenever possible before maintenance work is performed on equipment that is contaminated with a pesticide chemical. Several of the exposure incidents described in his report could have been prevented if this practice were followed. However, the maintenance workers should be warned that even though the equipment is precleaned it may still be contaminated. Maintenance workers should be trained to recognize potential exposures because they have to work in many areas where the probability of exposure is high.

"Lock out" procedures can vary from plant to plant because of differences in equipment. However, some points are applicable to all "lock out" procedures, including power shutoff, material flow shutoff, and the wearing of the proper personal protective equipment for the maintenance operation being performed. Power shutoff generally includes relief of internal pressure as well as electrical and mechanical power shutoff. Maintenance safety manuals generally include procedures for locking the power off and posting signs to indicate that power should not be turned back on until the maintenance is completed. Material flow shutoff is similar to power shutoff. Procedures should include locking valves in a closed position, installing blinds (plugs) in the pipe, or removing a section of pipe to prevent pesticides from entering equipment. When precleaning procedures cannot be used, personal protective equipment must be worn when performing maintenance tasks to prevent exposures from occurring. The required equipment should be specified in the operations or safety manual.

When performing maintenance that requires a worker to enter a piece of equipment, the buddy and permit systems will help protect the worker from accidental exposure. The buddy system requires that a second employee be in visual and voice contact with the employee who entered the piece of equipment under repair. This contact is maintained throughout the maintenance process. The employees are also usually connected by a lifeline so that the employee who is inside the equipment can be pulled out if he is injured or poisoned. The permit system requires that the worker obtain a permit from a supervisor who, in turn, is responsible for ensuring that certain precautions have been taken before the permit is issued.

Support of Work Practices

Recommended work practices for materials handling procedures, housekeeping, personal hygiene, tank entry procedures, and use of personal protective equipment can successfully prevent worker exposure to pesticidal chemicals only if accepted and continuously observed by the worker. Employers can encourage worker acceptance of work practice controls by informing workers about the risks associated with their occupations and by supporting the work practice controls through proper supervision and utilization of administrative controls.

(a) Posting and Labeling

Recognition of danger is a significant factor in the prevention of injury or illness [29]. One of the findings of the NIOSH National Occupational Hazard Survey (NOHS) is that most workers are unaware of the hazards of their jobs [332]. The survey cites the widespread use of trade name products and the lack of a uniform labeling system as reasons why it is difficult for workers to know the chemical hazards to which they are exposed. Obviously, treatment of a poison victim is very difficult unless the chemical composition of the poison is known.

Blodgett and Musgrove [84], in summarizing hearings on Kepone contamination, stated that an epidemiologist who surveyed the Kepone facilities found no informational signs or posters to indicate that Kepone was hazardous.

Information about hazards, even though covered in a training program, should be available in the workplace as a reminder and reference for trained workers, and as a warning to others who may inadvertently enter a hazardous area. Labels should be applied to process equipment, and signs should be posted at points of access to hazardous operations.

EPA enforces requirements for labeling that are authorized under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and under the Federal Environmental Pesticide Control Act (FEPCA). These laws require labeling of all containers of pesticides that are commercially sold. Product labels must contain the common and chemical names, signal words if required, such as danger, warning, and caution, and first-aid procedures in case of an accident. EPA does not require that labels be affixed to process equipment or to containers other than those in which pesticides are distributed for sale. In addition, the labels required by EPA do not include information concerning safe work practices and use of protective equipment. Product label requirements are based on toxicity of the final product. Some active ingredients, in concentrated form, may be more toxic than the label indicates. Thus, there are several situations in the workplace where product labels do not provide sufficient information to assure protection from overexposure.

In a pesticide manufacturing or formulating plant, anything that contains a pesticidal chemical--including drums, bags, and processing equipment--should be labeled to indicate contents and hazards. Signs should be posted to aid workers in determining what type of respirator and other protective equipment to use. Signs should also indicate what to do in the event of an emergency or spill. Some of the labeling practices observed during site visits [8(pp 58,98)] to pesticide plants include content and hazard labels on product containers, content and pressure labels on reaction vessels to prevent premature opening of a pressurized tank, color-coded pipes, and directional flow labels on pipes. Other signs observed on site visits [8(pp 5,38,91)] include "No Smoking" signs and reminders to wash hands and observe other personal hygiene requirements.

Posting various safety and health warnings in conspicuous areas within the plant informs workers of hazardous operations. Posters or signs should be used to warn workers about protective equipment required for entry to and limited access of restricted areas, to identify emergency equipment and exits, and to specify procedures for operations such as maintenance or repair of process equipment. When maintenance is in progress and the potential for exposure increases, signs should be posted to inform workers that such operations are taking place.

Generally, labels and signs support other recommended work practices by identifying areas where those practices are required and by warning of specific hazards associated with pesticide products.

(b) Training

The recognition of danger is especially difficult when there are no immediate acute effects. Without special training regarding the chronic effects of workplace chemicals, the methods to avcid exposure, and the symptoms of exposure, workers may become chronically overexposed to pesticidal chemicals. The following cases demonstrate instances in which workers' lack of awareness of toxic effects of the chemicals they handled contributed to their overexposure.

Hine [112] reported that 9 of 10 workers overexposed to methyl bromide were not informed of the hazard of that fumigant. Four of these overexposures resulted in fatalities. In an incident reported by Vale and Scott [37], a woman suffered severe poisoning and neurologic damage while employed in a plant formulating a preparation of demeton-S-methyl, an OP insecticide. The woman was never told in any detail of the possible effects of exposure to the products with which she was working. She had, for example, never realized that the abdominal cramps she had occasionally experienced were probably due to the demeton-S-methyl exposure, or that pinpoint pupils were another sign of exposure.

Training is an important component of any program to reduce worker exposure to hazardous chemicals or physical agents. The Occupational Safety and Health Act requires employers to provide their employees with training that will enable them to understand the nature of hazards to which they are exposed and effective methods to protect themselves. Training for supervisors should also include detailed information on emergency procedures. A National Research Council (NRC) study [333] on informing workers about cancer and other occupational illnesses suggested that workers be given a broad understanding of the hazards associated with their occupation. The study recommended that training include substance identification, location in the workplace, routes of exposure, measures to reduce exposure, signs and symptoms of overexposure and health consequences (even when extrapolated from animal data), proper use and maintenance of personal protective equipment, emergency procedures, and first aid. The last three items are particularly important.

Personal protective equipment is not effective if used improperly. A worker using an air-purifying respirator in an environment where the concentration of the contaminant exceeds the capacity of the respirator's filtering medium is not protected from overexposure. Similarly, a worker wearing a respirator that fits poorly is not adequately protected. Failure to wear personal protective equipment in areas where exposure is possible is a frequent occurrence when workers do not fully understand the serious nature of the hazard involved.

The training program should describe the role of each work practice in reducing potential exposure. The need for and value of each work practice should be clearly understood by the worker. The employee who is able to recognize the hazard and knows the means to control it is better equipped to protect himself from exposure. If the employee recognizes symptoms of exposure, he or she can request medical attention sooner. Detection of the odor of a pesticide being handled while wearing a respirator should be recognized by the worker as a warning that the respirator is not functioning properly.

In summary, the training requirements are intended to reinforce the other work practices by enabling the worker to understand the nature of the hazards associated with pesticidal chemicals and how to avoid overexposure. Worker acceptance of recommended work practices as well as an understanding of and the ability to avoid chronic health hazards can be improved through training.

(c) Supervision

Inadequate supervision was described as a cause of overexposure in a case in which a man was mixing 2,4-dichloro-6-(o-chloroanilino)-s-triazine in a tank when he began to notice itching and burning of his face and hands. A physician gave him local and systemic steroids for treatment of his rash. He had been provided with protective clothing but might not have used it at all times. In addition, some of the containers were not labeled to require the use of protective equipment [297].

An employee cleaning a pump used in mevinphos production at a formulation plant was overexposed as the result of not wearing recommended safety equipment. He reported to a physician with symptoms that included miosis, excessive salivation, and excessive perspiration. He was hospitalized. His employer was issued a notice of violation for lack of adequate supervision of employees [297].

Inadequate supervision was indicated as a causal factor in some of the accidental overexposures to pesticides discussed earlier. The relationship between supervision and the implementation of good work practices is evident in most industrial situations. The potential is always present for production requirements to conflict with work procedures designed to prevent injury or illness. To protect workers' health in a pesticide plant, it is essential for supervisory personnel to be cognizant of the potential risks that occur to workers when proper work practices are not followed. Supervisors should be present to assure that proper procedures are followed during start-up, loading and unloading, and during tank entry operations. Supervisors should also be prepared to direct other workers during emergency situations. Occasional checks should be made to be certain that personal protective equipment and protective clothing are properly worn. Supervisors should also know and watch for signs of overexposure to pesticides and should recommend medical attention for workers who exhibit signs of overexposure. One positive strategy for concerned management would be to rate supervisory personnel on understanding and implementing safe and healthful work practices in addition to normal factors such as productivity and economy of operation.

(d) Administrative Controls

Administrative controls are actions taken by the employer to schedule operations and work assignments in a way that minimizes the extent, severity, and variety of potential exposure. For example, only necessary personnel should be permitted to work in areas where there is a high risk of exposure. The duration of exposure may also be reduced by rotating employees between assignments that involve exposure and those that do not. Minimizing the number of different pesticides that an individual worker is exposed to is also desirable. This practice would make it easier to monitor effects and, more importantly, would avoid possible synergistic effects that may result when exposure to several different chemicals occurs.

There are four activities that can support work practices: labeling and posting, training, supervision, and administrative contols. The emphasis in training should be on developing good work practices to prevent emergencies, accidents, injuries, and overexposures. The educational process should be reinforced through labeling and posting that identifies hazards and repeats information concerning proper procedures. Labels and signs also serve as warnings to uninformed individuals in the plant. Supervision is an essential element in the proper implementation of good work practices as well as a resource for dealing with emergency situations or for observing signs of overexposure in workers. Finally, administrative control is an additional method of minimizing worker exposure through allocation of work assignments and in conjunction with other recommended work practices.