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Adverse Health Effects of Pesticide Exposure in Agricultural and Industrial Workers of Developing Country

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1. Introduction

Pesticides are used extensively throughout the world. There are several definitions of pesticide; the Food and Agriculture Organization of the United Nations (FAO) defines pesticide as any substance or mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage or marketing of food, agricultural commodities, wood and wood products or animal food stuffs or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies (FAO, 1986).

Pesticides are playing a pivotal role in meeting the food, cotton fibre and tobacco demand of escalating population and control of vector-borne diseases. However, most of the applied pesticides get dispersed in the environment and affects the health of un-protected agricultural and industrial workers. The three major routes of entry for pesticides include contamination of the skin, lungs and the gut. The skin of a human adult has a superficial surface area of approximately 1.73 m², but it is undoubtedly the major focus of accidental acute exposure. Similarly the respiratory tract provides a very efficient surface for the absorption of substances, whether they are in the form of vapors, particles or droplets. Although pesticides furnish some benefits for crop, they entail a number of risks and problems. The public health issue of pesticide exposure is further complicated by the presence of impurities in so-called, inert-ingredients such as solvents, wetting agents and emulsifiers. These chemicals are suspected of producing adverse health effects based on their structural similarity to proven toxicants. The unregulated and excessive use of pesticides has become a major bottleneck in our fight against insect pests.

Exposure to pesticides is one of the most important occupational risks among farmers in developing countries (Wesseling et al., 2001; Konradsen et al., 2003; Coronado et al. 2004). Occupational exposure to pesticides is of great interest in order to identify the hazards of pesticide use and the establishment of safe methods of pesticide handling. This is because

pesticide misuse in various sectors of the agriculture often has been associated with health problems and environmental contamination worldwide (Soares et al., 2003; Mancini et al., 2005; Remor et al., 2009). Misuse of highly toxic pesticides, coupled with a weak or a totally absent legislative framework in the use of pesticides, is one of the major reasons for the high incidence of pesticide poisoning in developing countries (Konradsen et al., 2003). Low education levels of the rural population, lack of information and training on pesticide safety, poor spraying technology, and inadequate personal protection during pesticide use have been reported to play a major role in the intoxication scenario (Hurtig et al., 2003; Atreya, 2008). In general, knowledge of the main determinants of pesticide exposure in developing countries is often poor and also exposure situations may differ among countries.

A major factor of pesticide contamination or poisoning in developing countries is the unsafe use or misuse of pesticides. Elements of unsafe use of pesticides that have been identified by past research include erroneous beliefs of farmers about pesticide toxicity, lack of attention to safety precautions, environmental hazards, and information about first aid and antidotes given by the label, the use of faulty spraying equipment or lack of proper maintenance of spraying equipment, and lack of the use of protective gear and appropriate clothing during handling of pesticides (Hurtig et al., 2003; Damalas et al., 2006a, 2006b; Ajayi and Akinnifesi, 2008; Chalermphol and Shivakoti, 2009; Plianbangchang et al., 2009; Sosan and Akingbohunge, 2009). Extensive use of domestic utensils and broken equipment for measuring and dispensing pesticides in developing countries often continue unabated because farmers cannot afford equipment that is in good working condition. In view of the adverse health effects from the unsafe pesticide use, the latency of the adverse effects, the reported lack of awareness of the adverse health effects of pesticides by some farmers, and the erroneous belief of invincibility by others, it becomes imperative that the potential hazards of unsafe pesticide use should be clearly communicated to the farmers. Fortunately, many farmers have expressed the need for information and training programs on pesticide safety, and therefore are likely to be responsive to such programs. Research has often emphasized the need to increase the awareness of farmers about the consequences of unsafe pesticide use and the importance of communication and education programs aiming to reduction of risk (Ibitayo, 2006; Hashemi et al., 2008; Oluwole and Cheke, 2009; Sosan and Akingbohunge, 2009; Damalas and Hashemi, 2010). Incorrect beliefs about pesticides and hazards often associated with pesticide use can reduce the capacity of farmers to protect themselves against these hazards. However, the first step in developing pesticide hazard reduction programs is to identify the extent of the problem by investigating farmers' knowledge, attitudes, and perceptions about pesticide handling and pesticide safety. Agricultural extension is a major channel of communication between farmers and research experts which can improve crop production from many points of view as it provides a good link between farmers and research institutes where several agricultural technologies, including pesticides and the relative technology, are developed, tested, and modified accordingly. Training programs can play a crucial role in pest control decisions, providing farmers with the technical knowledge that is necessary for the selection of appropriate pest management methods and also for safe and effective pesticide use. Despite the appearance of homogeneity, often small farmers have different production practices, needs, and constraints (Carr, 1989). A successful agricultural extension program, therefore, should not consider all individuals in a target group based on several variables such as age, gender, income, and types of crops.

1.1 WHO classification of pesticide

Toxicity of formulated chemical product classified according to WHO hazard classes (table-1). Pesticide belonging to WHO class 1a is extremely hazardous, class 1b is highly hazardous, class 1c is moderately hazardous, class 1d is slightly hazardous and class 1V is unlikely to present acute serious hazards in normal use (WHO, 2000). Nearly 90 percent of the banned pesticides fall into category 1a/ 1b/1c of the WHO hazard grades. Applications of monocrotophos, cypermethrin, methamidophos and dimethoate have been increased many folds in Pakistan (Tariq et al., 2007).

1.2 Organophosphates

They were developed during the early 19th century, but their effects on insects, which are similar to their effects on humans, were discovered in 1932. Some are very poisonous (they were used in World War II as nerve agents). They are generally highly lipid soluble and may be classified as direct or indirect acetylcholinesterase (AChE) inhibitors. However; they usually do not persist in the environment. The organophosphates (OPs), because of their widespread use and frequently high acute toxicity, are involved in more pesticide poisonings than any other class of pesticides. The organophosphates interfere with the activity of cholinesterase. When the cholinesterase enzyme cannot perform its normal function, the nerves in the body send "messages" to the muscles continuously leading to muscle twitching and weakness. If the poisoning is severe, the victim may have "fits" or convulsions and may even die. Organophosphates are irreversible cholinesterase inhibitors, without medical treatment the level of enzyme activity will return to normal only after several days, weeks or even months. Additive effects of small repeated doses over time, such as in a spraying season, may finally cause poisoning. The effects of mild poisoning include fatigue, headache, and dizziness. Moderate poisoning leads to inability to walk, weakness and chest discomfort. In severe cases there will be unconsciousness, severe constriction of pupils and muscle twitching ultimately resulting in death.

1.3 Methamidophos

It is classified by Environmental Protection Agency (EPA) as a class I compound. Methamidophos is a highly active, systemic, residual organophosphate insecticide/ acaricide/avicide with contact and stomach action. Methamidophos, a potent acetylcholinesterase inhibitor, is highly toxic via oral, dermal and inhalation routes. Early symptoms of acute organophosphate poisoning are dependent on route of exposure, and usually develop during or shortly after exposure (within 12 hours). Weakness, shakiness, blurred vision, tightness in the chest, sweating, confusion, changes in heart rate, convulsions, coma, and cessation of breathing may occur with significant inhalation, ingestion or dermal exposure. The Allowable Daily Intake (ADI) level of methamidophos is 0.0003 mg/kg.

1.4 Carbamates

The effects of carbamates and organophosphates are similar because they both inhibit cholinesterase. Action of carbamates is naturally reversible as compared to methamidophos action of carbamates is naturally reversible (they will be degraded in and/or expelled from the body). Thus, carbamates can cause severe severe poisoning, but they do not normally produce long-term, cumulative poisoning. The symptoms of acute carbamate and organophosphate poisoning are essentially the same.

Pesticide product	Active ingredient	Chemical class	Toxicological class*	Main use
BASUDIN	Diazinon	Organophosphates	II	Insecticide
HERBOXONE	2,4-D	Chlorophenoxy acids	II	Herbicide
TOPIK	Clodinafop-propargyl	Aryloxyphenoxypropionics	III	Herbicide
AATREX	Atrazine q	Triazines	U	Herbicide
MACHETE	Butachlor	Chloroacetanilides	U	Herbicide
CERTAINTY	Sulfosulfuron	Sulfonylureas	U	Herbicide
ERADICANE	EPTC	Carbamides	II	Herbicide
LASSO	Alachlor	Chloroacetanilides	III	Herbicide
DECIS	Deltamethrin	Pyrethroids	II	Insecticide
ALTO	Cyproconazole	Triazoles	III	Fungicide
SENCOR	Metribuzin	Triazines	II	Herbicide
CONFIDOR	Imidacloprid	Neonicotinoids	II	Insecticide
GRANSTAR	Tribenuron-methyl	Sulfonylureas	U	Herbicide

* Ia = Extremely hazardous; Ib = Highly hazardous; II = Moderately hazardous; III = Slightly hazardous; U = Unlikely to present acute hazard in normal use

Table 1. Classification of pesticides used by the farmers surveyed

1.5 Methomyl

Methomyl is a carbamate insecticide. It is broad spectrum fast acting anti-cholinesterase agent. It is a direct contact and stomach poison. It is a plant systemic of high acute toxicity to mammals. It is non-cumulative and rapidly metabolized in both plants and animals to substances of lower toxicity. Methomyl is particularly effective against organophosphorus resistant pests. Methomyl may be absorbed from the gastrointestinal tract, through the intact skin, and, by inhalation of spray mist and dust. The ADI levels of methomyl are 0.01mg/kg.

1.6 Thiodicarb

It is a carbamate pesticide and belongs to class II, moderately hazardous pesticide. Symptoms ymptoms include malaise, muscle weakness, dizziness, sweating headache, salivation, nausea, vomiting, abdominal pain, diarrhea, central nervous system depression and pulmonary edema. The ADI levels of thiodicarb is 0.03 mg/kg.

1.7 Organochlorines

They were commonly used in the past, but many have been removed from the market due to their health and environmental effects and their persistence (e.g. DDT and chlordane).

1.8 Endosulfan

It is an organochlorine pesticide of moderate mammalian toxicity which does not accumulate in the tissues of man or animals to any significant extent. Undiluted endosulfan is slowly and incompletely absorbed in the gastrointestinal tract of warm-blooded animals. Absorption is more rapid in the presence of alcohols, oils and emulsifiers. These substances also accelerate the absorption of endosulfan through skin. It is a central nervous system stimulant, producing convulsions. The ADI level of endosulfan is 0.006 mg/kg.

2. Synthetic organic pesticides

Since the 1940s, pesticide use has expanded because of the development of the synthetic organic compounds. The synthetic organic pesticides (i.e., man-made, carbon-containing chemicals) include the chemical groups; chlorinated hydrocarbons, organophosphates, carbamates, pyrethroids, phenoxy herbicides and a number of other chemical classes. Groups with similar chemical structure tend to be similar in their mode of action, fate in the environment and pest control properties, but not necessarily in their level of toxicity. Though pesticides may have different chemical structures, they can have similar modes of actions. Their activity tends to be highly specific, and they are often harmless to non target species.

2.1 Pyrethroids

They were developed as a synthetic version of the naturally occurring pesticide pyrethrin, which is found in chrysanthemums. They have been modified to increase their stability in the environment. Some synthetic pyrethroids are toxic to the nervous system.

2.2 Cypermethrin

It is a composite pyrethroid; a broad spectrum, non-cumulative insecticide and a fast-acting neurotoxin with good contact and stomach action. It has of moderately high toxicity to mammals and readily metabolized with immediate loss of activity. Cypermethrin is not a plant systemic, it is readily degraded on soil or plants but has good residual activity on inert surfaces. Cypermethrin is primarily absorbed from the gastrointestinal tract. It may also be absorbed by inhalation of spray mist and only minimally through the intact skin. The ADI level of cypermethrin is 0.05 mg/kg.

2.3 Imidacloprid

Acetylcholine esterase enzyme inhibitor when compared to many older synthetic pesticides imidacloprid, is only moderately toxic to mammals, including humans. It is, however, highly toxic to other "non-target" and beneficial insect species. So, as always, care should be taken to avoid misapplication. The ADI level of imidacloprid is 0.06 mg/kg.

3. Pesticide uses

Modern agricultural practices especially the use of pesticides and fertilizers have brought about green revolution in many countries and have infact provided global food security. While pesticide uses have improved world food supply and have been responsible for

better growth and yield, their irresponsible and indiscriminate uses have greatly increased environmental health problems. There are more than 1000 agrochemicals which are being manufactured and used for agriculture as well as public health purposes. Pesticides are an essential tool for increasing the agricultural production. To produce good crop, favorable conditions and suitable chemicals are required. Pakistan is basically an agricultural country, with its economy largely depending upon a good crop yield. Pesticide usage has been undergoing a steady increase in Pakistan, along with the rest of the world. To support a large human population of about 180 million only 254 metric tons of pesticide formulation was used in 1954, however, annual production of pesticides by 18 member companies of the Pakistan Agricultural Pesticide Association (PAPA) was 23,457 and 18,774 metric tons, in the year 1998 and 1999, respectively. The Asia-pacific region is predominantly an insecticide market. National and multinational companies are engaged in the lucrative business of formulating these pesticides in Pakistan. In Pakistan, organophosphorus insecticides dominate the market with 37 percent share, followed by carbamates (23%), synthetic pyrethroids (22%), biopesticides (12%) and organochlorines (6%). In pesticide industry, the principal pollutants are a variety of the active pesticide ingredients, solvents, and other chemicals, wasted during the process, in the form of waste chemicals, solid waste, waste water and air emissions. The pesticides packaging industries in Pakistan are contributing relatively high quantities of toxic pesticides in the environment, as most of them have either no treatment facilities or have grossly inadequate handling arrangements. Moreover, there is no concept of personnel safety in our most of the pesticides industries.

4. Pesticide exposure

Pesticides exposure occurs in different ways in different ways: dermal, oral, respiratory and conjunctival routes.

4.1 Dermal exposure

It occurs by not washing hands after handling pesticides or their containers. Splashing or spilling of pesticide on skin by wearing pesticide-contaminated clothing and applying pesticides in the windy weather. Touching treated plants or soil also leads to dermal exposure. Exposures occur by rubbing eyes or forehead with pesticides contaminated gloves or hands, splashing pesticides in eyes, application in windy weather, drift exposure and mixing/loading of dry formulations without wearing goggles.

4.2 Oral exposure

Hands not washed before eating, smoking or chewing, pesticide splashed into mouth. Accidental application of pesticides to food, storing pesticides in drinking containers and drift on lip or in mouth also leads to oral exposure.

4.3 Inhalational exposure

Exposed to drift during or after spraying, mixing/loading, dusts, powders or other dry formulations. Use of inadequate or poorly fitted respirators.

5. Pesticides poisonings

Agro-chemical industry has offered thousands of compounds. The climatic condition of Pakistan favors pest build up that destroys about 20 percent of potential agricultural crop. The health of the pesticides handlers and farmers in particular are at high risks due to irrational use of pesticides.

Pesticides cause the acute and chronic health effects; organophosphate and carbamate groups are more important. These insecticides inhibit cholinesterase, an enzyme critical for normal functioning of the nervous system

5.1 Prevalence of pesticides poisoning

In USA, more than 18,000 products are licensed for use and each year more than 2 billion pounds of pesticides are applied to crops, gardens, in homes etc. (U.S EPA, 2002). The major economic and environmental losses due to the application of pesticides in public health were 1.1 billion dollars per year in USA (Pimentel, 2005). Such wide spread use results in pervasive human exposure. Evidence continues to accumulate that pesticide exposure is associated with impaired health. Occupational exposure is known to result in an annual incidence of 18 cases of pesticides related illness for every 100,000 workers in U.S (Calvert et al., 2004). Pesticide poisoning is a major public health problem in many developing countries (Xue et al., 1987; Jeyaratnam, 1990). In developing world, pesticide poisoning causes more deaths than infectious diseases. Pesticide poisoning among farmers and occupational workers in developing countries is alarming (McCauley et al., 2006).

WHO estimated approximately 20,000 workers die from exposure every year, the majority in developing countries (Pimentel et al., 1992; Kishi et al., 1995). The number of intoxications with organophosphates is estimated at some 3000,000 per year and the number of deaths and casualties some 300,000 per year (Peter, 2003). Ahmed and co workers have reported 64 percent of fatal cases of acute pesticides poisoning in Multan, Pakistan occurred due to OPs pesticide spraying (Ahmed et al., 2002) However another study revealed 21 percent of occupational pesticides poisoning in hospitalized patient (Afzal et al., 2006).

5.2 Acute toxicity

Organophosphorous compound exert acute systemic toxicity by inhibiting the enzymes AChE through a process of phosphorylation. Pesticides bind to cholinesterase and block the hydrolysis of the acetylcholine and acetic acid at the post synaptic junctions without junctioning acetyl cholinesterase; acetylcholine accumulates (Chan and Critchley, 1998; Mason, 2000). OPs induced neuronal symptoms are a consequence of axonal death. Following OPs exposures inhibition of neuronal enzymes, called neuropathy target esterase, occurs and many of them are irreversible.

6. Health effects of pesticide

6.1 Hepatic dysfunctions

Liver enzymes may be used to detect the effect of pesticides before adverse clinical health effects occur (EI-Demerdash et al., 2001). Prolonged exposure to multiple pesticide, affected liver and kidney (Azmi et al., 2006). There is also an increase in the prevalence of liver

disorders among Ranch Hand workers in high exposure category (Michalek et al., 2001). Statistically significant aspartate aminotransferase (AST) levels were found in agriculture workers continuously exposed to pesticides (Hernandez et al., 2006). Higher levels of gamma glutamyl transferase (GGT), (GOT), were found in the blood of occupational workers chronically exposed to pesticides (Michalek et al., 2001; Misra et al., 1985). An increased rise of liver dysfunction was observed with elevated (AST), alanine aminotransferase (ALT), or lactate dehydrogenase (LDH) (Michalek et al., 2001; El Demerdash et al., 2001). AST and ALT are involved in the breakdown of amino acids into α -keto acid, which are routed for complete metabolism through the Krebs' cycle and electron transport chain. Consequently they are considered as a specific indicator for liver damage (Harper, 1979). The increased activity of serum AST and ALT indicated hepatocellular dysfunctions (Yousaf et al., 2006). A positive correlation of pesticides with the liver enzymes has been reported by many researchers (Carvalho, 1991; Azmi et al., 2006).

In vivo and in vitro studies showed that organophosphorous, organochlorine and pyrethroids pesticides caused increase of LDH activity (Bagchi et al., 1995; Yousaf et al., 2006). LDH is used as an indicator for cellular damage and cytotoxicity in pesticides exposure (Bagchi et al., 1995).

Subtle nephrotoxic changes in workers occupationally exposed to pesticides with higher levels of serum creatinine and or blood urea have been reported (Kossomann et al., 2001; Al Qarawri and Adam, 2003). Serum creatinine was also significant in intensive agriculture workers or applicators and pesticides plant workers (Hernandez et al., 2006; Attia, 2006).

Various animal studies also revealed similar findings.

Among other serum markers serum phosphorous was also found to be significantly high in prolonged pesticides exposures (Hernandez et al., 2006). Previous epidemiological studies reported phosphorous levels beyond the normal range in 7 percent of pesticide applicators (Parron et al., 1996).

6.2 Nephrotoxic effects

Cholinesterase inhibitor poisoning has both short and long term neuropsychological sequelae (Tapi et al., 2005). Recent studies have examined a link between pesticides exposure and neurological outcome (Kamel and Hoppin 2004). OPs being inhibitors of esterases lead to the accumulation of acetylcholine at nerve endings leading to cholinergic crises, by initial stimulation and eventually exhaustion of cholinergic synapses (Singh and Sharma, 2000). Clinical features reported anxiety depression, irritability, psychotic symptoms, and erectile disorders were more significant in pesticides applicators than controls (Amr et al., 1997). Chronic low-dose exposure leads to the neuropsychiatric consequences among the tobacco agricultural workers in Brazil (Salvi et al., 2003). Intermediate syndrome is a major cause of morbidity and mortality in patients with acute OP poisoning (Yang and Deng, 2007).

6.3 Chronic toxicity

Delayed effects of pesticide are illnesses or injuries that do not appear immediately (within 24 hours) after exposure to a pesticide. Adverse effects may be delayed for weeks, months or even years after the first exposure to a pesticide. Depending upon the toxicity of the

compound, dosage and exposure time, the adverse effects of pesticides poisoning ranges from headaches, vomiting, skin irritation, respiratory problems to other neurological disorders (Jors et al., 2006). Available evidence suggest that there is a possibility of adverse effects occurring below OP compounds concentrations that are generally considered to be safe based on measurement of AChE inhibition (Singh and Sharma, 2000; Salvi et al., 2003). A study in Srilanka has shown inhibition of AChE enzyme and impairment of sensory and motor nerve conduction due to long term, low level exposure to OPs. (Smit et al., 2003). Farm workers and green house workers exposed to organophosphates reported more symptoms than unexposed workers (Strong et al., 2004). Pesticide poisoning is associated with increased symptom prevalence (Kamel and Hoppin, 2004; Jors et al., 2006). Farmers and farm workers who applied organophosphate had higher symptoms prevalence than did non applicators (London et al., 1998; Beshwari et al., 1999; Ohayo-Mitoko et al., 2000). Farm workers with little access to information about safety practices or protective equipment may sustain for more exposure (Pimetal et al., 1992). Diverse trends were seen regarding the disposal of pesticide residues. Due to casual attitude towards the handling of pesticide, many farmers threw pesticide containers in field or irrigating water which increases environmental pollution and health hazards in the community. This malpractice causes increased pesticide residues in human blood and water (Ansari et al., 1997; Ahad et al., 2006). The health effects of low dose pesticides exposure are very difficult to evaluate mostly when pesticides mixtures are used (Lewalter and Leng, 1999; Carpy et al., 2000).

6.4 Carcinogenesis

Epidemiological studies have implicated pesticides as causative agent in human cancer (Zahm and Blair, 1992). Cancer and even death is more frequent among farmers rather than general population (Gertrudis et al., 2001). Cytogenetic studies showed an increase in DNA damage and higher chromosomal aberrations (CAs) in exposed farmers compared to the control subjects (Naravaneni, 2007). A study documented significant genotoxic exposure of pesticides on the basis of significant decrease in the level of serum ChE among workers involved in pesticide manufacturing industry (Bhalli et al., 2006). There was an increased risk of lung cancer reported in German agricultural workers, which also increased with the length of exposure (Barthel, 1981).

6.5 Oxidative stress

Recent studies have shown that oxidative stress could be an important component of the mechanism of OP compound toxicity. Several studies explained that oxidative stress is involved in OPs toxicity (Parakasam, 2001; Hsu et al., 2001). Repeated daily oral doses of pesticide in rats altered the biochemical parameters and antioxidant status (Manna, 2004). Several studies reveal that OPs may induce oxidative stress leading to generation of free radicals and alteration of antioxidant status (Bagchi, 1995; Abdhollahi, 2004). Toxic effects of pesticide on human beings especially by omitting radical production can be confirmed by the direct measurement of lipid per oxidation by-product malondialdehyde (MDA), (Muniz et al., 2007). Our study revealed a significant rise in Plasma malondialdehyde (MDA) levels in exposed farmers than in controls. The results of our study were consistent with other studies suggesting that pesticides increase oxidative stress in humans (Prakasam et al 2001;

Singh et al., 2007). There is increasing evidence that OP and carbamate induced oxidative stress through the generation of free oxygen radicals, leading to lipid peroxidation and DNA damage (Hazarika et al., 2003; Abdollahi et al., 2004; Vidyasagar et al., 2004; Shadnia et al., 2005). Muniz and co workers reported MDA levels 4.9 times and 24 times higher in farm workers and applicators respectively than in controls (Muniz et al., 2007). Pesticides induce a wide array of human health effects through oxidative stress causing cytogenetic damage and carcinogenicity (Mansour, 2004).

7. Monitoring of pesticide exposure

The health effects of pesticides exposure are difficult to monitor in the farmers especially when mixture of pesticides are used over the period of time. The term biomarker is used to include almost any measurement reflecting an interaction between a biological system and an environmental agent, which may be chemical, physical, or biological. Biomarkers can be used to identify causal associations and to make better quantitative estimates of those associations at relevant levels of exposure (WHO, 1993). They may also make it possible to identify susceptible groups or individuals who are at risk of exposure to certain types of environmental and occupational agents. The advances in molecular genetic have led to an upsurge in trust in most susceptibility factors and identification of polymorphism of various enzymes has become possible (Vainio, 2001). Biomarkers include detection of the environmental substance itself or its metabolites in urine or blood, changes in genetic material, and cell death. The biological events detected can represent variation in the number, structure, or function of cellular or biochemical components. Recent advances in molecular and cellular biology allow for measurement of biological events or substances that may provide markers of exposure, effect, or susceptibility in humans. Two kinds of measurement have been used for assessing the exposure to pesticides which includes enzymes activity and pesticides residue in the blood.

Inhibition of plasma cholinesterase serves as a diagnostic tool for the risk assessment of exposure to toxic organophosphates (Amitai et al., 1998). Inhibition of AChE activity has been widely used to assess OPs exposure. A study revealed a high prevalence of pesticides poisoning in agricultural farmers by OPs and carbamates exposure with the reduction of AChE. Green house farm workers also showed the same results (Karabay et al., 2004). Low levels of serum cholinesterase on moderate and prolong pesticide exposure is also reported by many researchers (Gertrudis et al., 2001; Hernandez et al., 2004). Significant decreases in AChE levels were found in pesticides applicators (Kesovachandran et al., 2006). Acetyl cholinesterase activities significantly decrease at the period of maximum exposure to pesticides; pinpoints certain inhibitory effect of pesticides on this esterase (Hernandez et al., 2004; Jors et al., 2006). Decrease in levels of serum cholinesterase found higher in workers with prolong exposure than those with shorter exposures (Karabary et al., 2004; Bhalli et al., 2006). Inhibition of plasma cholinesterase serves as a diagnostic tool for the risk assessment of exposure to toxic OPs (Amitai et al., 1998). As the levels of AChE activity returns to normal within days to weeks after exposure to OPs. It thus serves as a measure for fairly recent exposure (Mason, 2000). Pesticides and their metabolites can be measured in biological samples, serum, fat, urine, blood, or breast milk by the usual analytical techniques or by biological method. A number of reports are available in which insecticides and/or

their metabolites have been measured in body fluids after occupational exposures (Coye, 1986). A positive effect will be indicative of exposure. Pesticides residual analysis is mainly done on High Performance Liquid Chromatography (HPLC) and Gas Chromatography (GC).

8. Factors effecting implementation of waste reduction

Several factors to affect the effectiveness of in-plant modifications and changes upon implementation of the waste reduction proposals can be identified as follows:

- i. manufacturing practices,
- ii. housekeeping and water conservation practices,
- iii. equipment operation and maintenance,
- iv. measurement of losses,
- v. attitude of workers,
- vi. education and training of personnel

Apparently, all factors are largely dependent upon the management stand on environmental issues. Key environmental issues associated with the industry, in order of their significance, are as follows:

8.1 Environmental and public health impacts

All pesticides are potentially toxic and hazardous to human beings. Severity of hazard, posed by a pesticide, depends on its toxicity, route of exposure, whether oral, dermal or inhalation, and the extent of exposure. Xylene and methyl ethyl ketone are the most commonly used solvents for pesticides. Short term exposure to high doses can cause irritation of the skin, eyes, nose and throat, difficulty in breathing, impaired functioning of the lungs, delayed response to a visual stimulus, impaired memory, stomach discomfort and possible changes in the liver and kidneys. Both short and long term exposure can also affect the nervous system.

8.2 Waste chemicals and contaminated solid waste (Metcalf & Eddy, 1985)

The major source of waste chemicals and solid wastes, which are contaminated with pesticides include defective and expired bottles and containers, expired pesticides, corrugated board carton, waste cotton rags, saw dust, spent (charcoal and activated carbon) and emptied drums. Current disposal practices being followed in some units in Pakistan includes, carrying out open burning of the plastic bottles, along with other contaminated waste either within the factory premises or at some remote areas. Some of the units have installed their own in-house incinerators to dispose waste whereas some units use commercial incineration facilities to dispose their contaminated wastes.

Generally the contaminated solid wastes are collected separately in waste bins and stored, till further disposal. During storage, in most cases, the waste chemical drums and different contaminated solid wastes are not placed on impervious floors. This can lead to contamination of soil and groundwater, consequent to any leakage and spillage.

8.3 Air pollution

Principal emissions, from the liquid pesticides pumping, formulation and filling facilities, are the vapors and fumes of active ingredients and organic solvents. Main emission from the

powder and granule pesticides filling units is toxic particulate matter. In-house waste incinerator (where provided) is another source of air emission. In order to minimize the dispersion of emissions into the general working air, most of the pesticides units have installed spot or local forced ventilation systems. Some of the treatment methods used is charcoal or activated carbon adsorption filters, fabric bag filters and wet scrubbers.

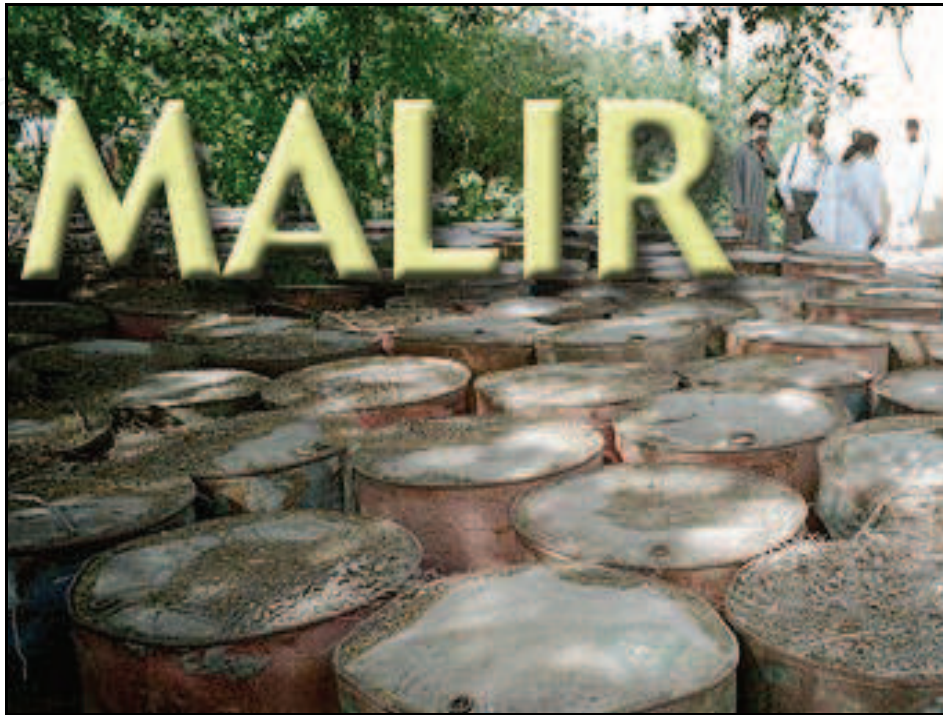


Fig. 1. Improper pesticide storage



Fig. 2. Corroded pesticide container



Fig. 3. Extensive pesticide usage

8.4 Occupational health and safety (OHS)

Most of the units are seriously concerned with workers health issues. Generally, they have their own OHS plans and policies, which they endeavour to, implement and follow. Following OHS issues, which require more attention are identified because without following these practices a proper assessment of the workers exposure cannot be made:

- i. Most of the units are not carrying out the required monitoring of the working air quality, with respect to pesticides and solvents.
- ii. Records of accidents and disease are not being properly maintained.
- iii. Many of the antidotes are not available readily in the market, this situation is not satisfactory to cope with emergency.



Fig. 4. Improper handling of pesticides



Fig. 5. Poor house keeping of pesticides

8.5 Water pollution

Pesticide plant has been operating to a significant degree of water wastage leading to a considerable amount of effluent generated. Possible sources of wastewater are as follows:

- i. Wet scrubbers are installed in some plants, the spent scrubbing liquid, discharged from these units, is quite high in pesticides contents.
- ii. Laundries practicing washing workers uniform discharge relatively large quantity of polluted wastewater.
- iii. The pesticide and organic solvents content in the floor washing wastewater, primarily, depend upon the floor cleaning method, consequently to any chemical spillage.

In some plants, the wastewater which has high pesticides contents is treated prior to its disposal to the drainage system. Plant operation data revealed that most of the colloidal and suspended pesticide contents can be separated from such wastewater, in the form of sludge, by the use of coagulation process at an increased pH value. The treated effluent is reported to have total pesticide contents within the permissible limits of National Environmental Quality Standards (NEQS).

8.6 Common process solid waste

This mainly comprises of the packaging waste, including damaged bottles, containers, cartons, plastic caps, labels and stickers, shrink wrappers, aluminum seals, polythene and paper bags and wooden pallets. Most of these are placed separately from contaminated waste and sold for down stream recycling and reuse. The generation of waste products of pesticides is given in Table 2.

8.7 Treatment

Industry has a modern wastewater treatment facility at their crop protection agricultural division. The Hoval pyrolytic non-polluting waste incinerator is especially designed to burn toxic waste materials at high temperatures required for destruction of toxic materials. The effluent treatment unit especially designed for treatment of agrochemical wastewater is able to reduce the concentration of chemicals in the raw effluent to less than 0.001 ppm.

The drum cleaning station is meant for washing empty steel drums, nowadays not in common practice in order to avoid rinsed water. The cleansed are then crushed in the drum crusher and disposed of in steel smelters.

Facilities	Installed Capacity	Capacity
	(Quantity per annum per shift)	utilized
Facility Number One	Liquid 25000 liters (per day)	20,000 liters (per day)
	Granules 8 tons (per day)	6 metric tons (per day)
Facility Number Two	Liquid 4.5 milli liters	Nil
	Powder 1.5 milli kilogram	0.75 milli kilogram
Facility Number Three	Liquid 1.44 milli liters	1 milli liters
	Granules 600 metric tons	Nil
	Powder 1200 metric tons	100 metric tons

Source: Based on data provided by Pakistan Agricultural Pesticides Association (PAPA), 2001

Table 2. Formulating capacities of three major industrial facilities operating in Pakistan

8.7.1 Incinerator

Equipped with the three burners termed as primary and secondary burners, quenching of the water is done automatically whenever required to achieve stable conditions.

Temperature of the primary burner is 500-750°C.

Temperature of the secondary burners 1000-1200°C (holding time is 2-seconds).

Usually solid and liquid wastes are handled by the incinerator: These include all types of plastics, papers, wood products, all expired production stock and active ingredients, solvents and washing water. Total Capacity of the incinerator is approximately 600 kg/ day.

8.8 Cleaner production (CP) techniques

In pesticide industry, the principal pollutants are the active pesticide chemicals and solvents, wasted during the process. Some measures for CP techniques are discussed:

8.8.1 Management of waste chemicals and contaminated solid waste

- i. All the waste chemicals and contaminated solid waste should be segregated from other wastes and properly stored, till their disposal.
- ii. The quantities, generation rates and pertinent characteristics of the wastes produced should be regularly measured and documented.
- iii. Incineration is considered to be a suitable technology for the disposal of waste chemicals and contaminated solid waste of pesticide industry.
- iv. Suggested contaminated waste incinerator, is rotary kiln type. The air emissions should be monitored for the applicable parameters, to check their conformity to the NEQS.

8.8.2 Air pollution control

There is a need to establish and monitor the occupational air quality, for the protection of the health and safety of the workers. The process of controlling the occupational air quality comprises the following sequential steps:

- i. Establishing the occupational air quality criteria for the protection of the health and safety of the workers.
- ii. Planning, design, installation and operation of a comprehensive system which ensures maintenance of the occupational air quality, within the desirable limits.
- iii. The workers carrying out activities close to the pollutant emissions sources should wear personal protection equipment.
- iv. The exhaust air carrying vapors and fumes from liquid pesticides processes should be treated with charcoal or activated carbon adsorption filters.

8.8.3 Occupational health and safety (WHO, 1996-1997)

- i. The Material safety data sheets (MSDS) should be readily available on site.
- ii. Due to high fire risk, the fire fighting system and emergency planning should be well established.
- iii. The management and the workers should be trained to avoid personal exposure to hazards and risks.
- iv. The antidotes should be stocked to handle emergency situations.

8.8.4 Reduction of water pollution

It is suggested that waste chemicals including pesticides as well as solids and solvents, should not be allowed to mix into wastewater streams, as far as possible.

- i. Unavoidable liquid pesticide spillage on floors, resulting from leakage and spilling of containers, vessels and process equipment, should not be cleaned by direct water washing, instead these should be dry cleaned, by absorption with sawdust or cotton rags.
- ii. The toxic particulate matter, emitted from the powder and granule filling machine should be separated by means of fabric bag filters, instead of wet scrubbers and the collected powder should be reused.
- iii. The tested samples from laboratory should be separately stored and treated as waste chemicals, for further proper disposal.

9. KAP information

The industrial workers' knowledge regarding the health hazards of pesticide and safety were assessed on the pre-tested questionnaire by the health team. A model questionnaire used in the study is given in Figure 6.

9.1 Knowledge

Among 184 workers, 62% were not literate and a few had completed their high school level education. Only the workers of FMC had formal training in safe pesticide handling and packing. Most of the workers (90%) had knowledge about the detrimental health effects of pesticide but were not well aware of the safety precautions regarding pesticide handling. However many workers reported to wash hands and bodies after work.

9.2 Attitude

The participants had casual attitude in handling of pesticide and personal protection. We observed that most workers of alpha chemical did not use any personal protective equipment (PPE) during pesticide handling while one industry chemical workers used masks. Farmers did use the gloves and face masks while mixing and filling of tanks. Another industry workers used proper protective head cover, gloves and masks during work.

9.3 Observed practices

Most workers of two industries wore traditional cotton shalwar kameez whereas third industry workers used cover all during work. Majority of the workers were unable to comprehend the safety instructions written in English. FMC workers pesticides exposure was regularly monitored by measuring ChE levels.

Name: _____ Age: _____ Gender: _____

Education: _____ Monthly Income: _____

Spray starting date: _____ Date of blood sample collection: _____

Baseline PChE: _____ Post exposure PChE: _____

Personal Protective Equipment

Gloves (Y/N)

Mask (Y/N)

Closed Shoes (Y/N)

Hand wash after spray (Y/N)

Body washes after spray (Y/N)

Cloths changed (Y/N)

Disposal of Pesticide

Water (Y/N)

Field (Y/N)

Dumping in soil/water (Y/N)

A standard questionnaire used for recording of clinical personal protective equipment information.

Fig. 6. A standard questionnaire used for recording clinical personal protective equipment information

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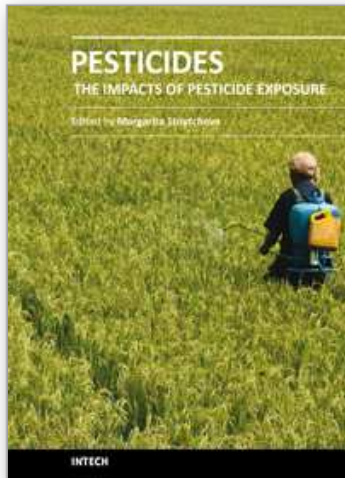
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Pesticides - The Impacts of Pesticides Exposure

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Pesticides are supposed to complete their intended function without “any unreasonable risk to man or the environment”. Pesticides approval and registration are performed “taking into account the economic, social and environmental costs and benefits of the use of any pesticide”. The present book documents the various adverse impacts of pesticides usage: pollution, dietary intake and health effects such as birth defects, neurological disorders, cancer and hormone disruption. Risk assessment methods and the involvement of molecular modeling to the knowledge of pesticides are highlighted, too. The volume summarizes the expertise of leading specialists from all over the world.

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