Health Concerns of Pesticides

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1 Introduction

In modern agriculture, pesticides are one of the major components for maintaining steady crop production. According to the Food and Agricultural Organization (FAO) of the United Nations, pesticides are substances or mixture of substances, intended for preventing, destroying or controlling any pest causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, and agricultural commodities. Pesticides are designed to control pests, weeds, and other plant pathogens; however, their mode of action is often nonspecific due to the presence of heterogeneous chemicals [1]. Pesticides often kill or harm organisms other than pests, including humans. Because of the improper and irrational use of different types of pesticides, the environment as well as the food chain (e.g. vegetables and fruits) may get contaminated with these chemical substances [2]. Individuals could exposed to pesticides or pesticide residues either through workplace or due to environmental contamination. Based on the level of contamination, these residues can affect different parts of the human body.

Individuals' reaction to pesticides varies with their level of sensitivity and immunity. For example, some people may show no reaction to an exposure of a specific pesticide, whereas it may cause severe illness to others [3]. Therefore, it is important to identify and assess the detrimental or negative effects of pesticides on human health. While determining the effects of pesticides on human body, it is necessary to consider certain key factors including route of exposure, dosing rates, chemical structure, absorption characteristics, types of pesticides and metabolites, and individual health condition [4].

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This article discusses the types and applications of pesticides, the acute and chronic effects of pesticides on human health, the intentional and unintentional ways of exposure to pesticides, and the immediate measures that should be taken after pesticides poisoning. This article also highlights the possible measures that should be taken when selling pesticides, and while applying pesticides at home or work place.

2 Health Effects of Different Types of Pesticides

On the basis of chemical structure, working principle, target molecules, and possible health effects, pesticides can be broadly classified as organochlorine pesticides, organophosphorous pesticides, carbamates, pyrithroids pesticides, biorational pesticides, and microbial pesticides [5]. The health effects of various pesticides are discussed in the following sections.

2.1 Organochlorine Pesticides

These pesticides are persistent organic pollutants (POPs), a class of chemicals that dissociate slowly in the environment, and accumulate in the fatty tissues of animals [6]. Hence, POPs stay in the environment and food web long after being applied [6]. Many POPs are endocrine disrupting chemicals, which can create subtle toxic effects on the hormonal system of the animal body [7]. Endocrine disrupting chemicals often mimic the natural hormones of the human body, disrupting the normal functions, and causing to adverse health effects [8].

Among its wide variations, the mostly used organochlorine pesticides are dichloro-diphenyl-trichloro-ethane (DDT) and its derivatives, such as hexachlorocyclohexane (HCH), aldrin and dieldrin. These POPs are widely used in many countries because of their low cost and versatility against pests. Due to their potential bioaccumulation and biological effects, these POPs have been already banned in different countries [9]; however, POPs are still available in the natural ecosystem [10]. Some of the names and related health effects of Organochlorine Pesticides are listed in Table 1 [4, 11–17].

2.2 Organophosphate Pesticides

Organophosphates (OPs) are produced from the reaction between phosphoric acid and alcohols. These substances are highly toxic in nature. Upon entering the body through ingestion, inhalation, or contact with skin, OPs may affect the human nervous system. OPs can also cause irreversible blockage leading to accumulation of

Table 1 Health effect of organochloride pesticides

Name	Health effect
1. BHC and its derivatives	Can harm the nervous system, β BHC alters thyroid hormone levels and can affect brain development; may cause cancer. [11], photosensativity, permanent hair loss [4]
2. α and ϒ Chlordane	Inhalation or ingestion may cause toxic effects, such as headaches, depression, anxiety, poor balance, tremors, and mental confusion; may cause cancer in animals [12]
3. Endosulfan 1, 2 and sulfate	Acutely neuro toxic; acute poisoning include hyperactivity, tremors, convulsions, lack of coordination, staggering, breathing, nausea and vomiting, diarrhea, and in severe cases, unconsciousness (Agency of Toxic Substances, 2013) [13]
4. DDD, DDE, DDT and their derivatives	May cause pancreatic cancer, non-Hodgkin's lymphoma, breast cancer, leukemia, skin sensitization, allergic reaction and rash [14], affect nervous system, cause prickling sensation of the mouth, nausea, dizziness, confusion, headache, lethargy, incoordination, vomiting, fatigue, and tremors; causes reproductive problems in rats and birds [15]
5. Aldrin and Dieldrin	Decreases the effectiveness of immune system, increase infant mortality, reduces reproductive success, causes cancer, birth, and kidney problem [16]
6. Endrin, Endrin aldehyde and Endrin ketone	Swallowing large amounts may cause convulsions, and lead to death within a few minutes or hours; less serious exposure result in headaches, dizziness, confusion, nervousness, nausea, vomiting [17]

the enzyme (cholinesterase), which results in fasciculation of muscles [18]. Some of the OPs are lipophilic, such as chloropyrifos, diazinon, parathion, and coumaphos, which can accumulate in body fat, and remain in the body for many days [19].

In humans, poisoning symptoms may include excessive sweating, salivation and lachrimation, nausea, vomiting, diarrhea, abdominal cramp, general weakness, headache, poor concentration and tremors. In serious cases, respiratory failure and death can occur. Even after several weeks of exposure, organophosphate induced delayed neuropathy (OPIDN) (i.e. nerve damage) may begin with burning and tingling sensations and progress to paralysis of the lower limbs [20]. Key health effects of OPs are:

Psychiatric effect Exposure to agricultural use of OPs causes depression, a major risk factor in suicides [21]. Researchers have found that suicide rates are higher in areas of greater OPs use [22].

Cardiac effects A number of studies have drawn attention to cardiac effects associated with occupational exposure to OPs [20]. Researchers have mentioned that OP exposer can cause slowing of the heart with decreased cardiac output [20] .

Eye defect Exposure to OPs during agricultural activities is related to an increased incidence of myopia (short-sightedness), and a more advanced ocular disease syndrome (Saku disease) [23].

2.3 Carbamate

Unlike organophosphates, carbamates are not structurally complex. Carbamates are applied either as powder or sprays. Carbamates may be absorbed through the skin, ingestion and/or inhalation. The immediate toxic effect of carbamates is very similar to that of organophosphates [24]. The short-term exposure of carbamate pesticides can cause muscle twitching, headache, nausea, dizziness, loss of memory, weakness, slow down heartbeat, tremor, diarrhea, sweating, salivation, tearing, and constriction of pupils. Long-term exposure of the carbamate can cause delayed neurotoxicity, such as tingling and burning in the extremities. This delayed neurotoxicity can progress to paralysis, which is seldom reversible. It may damage the liver, kidney, immune system, and bone marrow. Some carbamates are suspected carcinogens [25].

Carbamates insecticides act similarly on the nervous system, but have a shorter duration of action. Like OPs, they can affect the nervous system by inactivating the enzyme acetylcholinesterase [26]. Commonly used cabamates include aldicarb, carbofuran, carbaryl, ethienocarb, fenobucarb, oxamyl, and methomyl. These pesticides are widely used, and showed varying degrees of toxicity.

2.4 Pyrethroid Pesticides

Pyrethroid pesticides are potent neuro poisons, endocrine disruptors, and may cause paralysis [27, 28]. Pyrethroids are a synthetic version of pyrethrin, a natural insecticide, and are more stable in sunlight than pyrethrins. Pyrethroid pesticides are popular insecticides as they can easily pass through the exoskeleton of the insect. Deltamethrin and cypermethrin are the examples of pyrethroid pesticides [5].

2.5 Biorationals (Biorational Pesticides or Biopesticides)

Biorational or biopesticides are considered as relatively non-toxic to humans and environmentally safe. The EPA defines biorationals as “certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals” [5]. The effect of biopesticides depends on the interruption of natural growth processes of arthropods. They do not selectively attack any arthropod species, but generally have extremely low toxicity for vertebrates, including people. This group includes insect growth regulators (IGRs), chitin inhibitors, plant growth regulators, and chromosterilants [5].

2.6 Microbial Pesticides

Microbial pesticides kill arthropods either by releasing toxins or infections through microbial organisms. Two common microbial pesticides that fit are *Bacillus thuringiensis serotype israelensis* (Bti) bacteria and *Bacillus sphaericus* (Bs) bacteria [29]. Products from these bacteria are used to kill mosquito larvae; Bti also kills black fly larvae. Most microbial pesticides are more selective than biochemical pesticides [5]. The organisms used in microbial insecticides offer greater safety since they are nontoxic and nonpathogenic to wildlife, humans and other organisms. [30]

3 Mode of Exposure to Pesticides

The effect of pesticides on human body can be determined from the mode of exposures. Exposure to pesticides can occur in different ways and in different degrees. Figure 1 demonstrates classifications of pesticide exposure to the human body [4].

3.1 Unintentional Exposure

Unintentional exposure to pesticides through environmental contamination or work place is a common phenomenon [1]. The modes of unintentional exposure to pesticides can be broadly classified as occupational and non-occupational exposures.

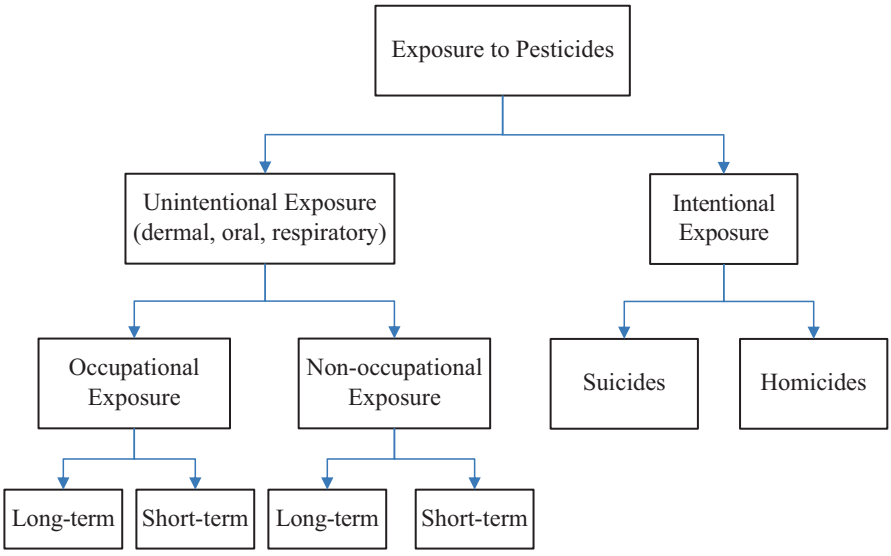

Fig. 1 Classifications of pesticide exposure to the human body [4]

3.1.1 Occupational Exposure

Workers involved in the agriculture sector, pesticide manufacturing industries, and other relevant sectors can easily get exposed to pesticides in their workplaces. In particular those who handle pesticides directly are at extremely high risks of exposure. Most occupational exposures to pesticides occur through inhalation or dermal contact, and in some cases through ocular exposure [31].

Agricultural workers Farmers directly or indirectly become exposed to pesticides during agricultural practices, and in the process of producing different kinds of crops, vegetables, and fruits. The possible ways agricultural workers may get exposed to pesticides are:

- by directly applying pesticides [32].
- by transporting, loading, and mixing pesticides [32].
- from accidental spills of chemicals, leakage, or faulty equipment [31]
- weather conditions at the time of application, such as air temperature and humidity, which may affect the volatility of the product, and the perspiration rate of the human body [33]
- by working close to pesticides applicators [34].

Furthermore, the frequent and long term handling of pesticides affects the human health. The exposure of an individual farmer who applies a pesticide once a year is lower than that of a commercial applicator, who typically applies pesticides for consecutive days or weeks during a particular season [33]. Several studies reported that agricultural workers suffer from eye burning, neurological effects, lever effects, and skin damages because of short term exposure to pesticides [4]. The genotoxicity of pesticides has been found positive in many agriculturists based on their exposure time and types of pesticides they use. For example, a study conducted on the agricultural workers employed at the Agronomic Institute of Brazil showed that there was a significant increase of chromosomal aberrations or damage (CA) frequency, in spite of using preventive measures [35].

Pesticides manufacturers Pesticides manufacturers are often in direct contact with pesticides. The workers working in the pesticide manufacturing units are directly exposed to the chemicals; employees working in the other units of pesticide manufacturing industries may also get exposed to pesticides directly and/or indirectly. Therefore, workers in the non-production units of these industries also face similar risky situations like the individuals who are exposed to pesticides on an agriculture farms [31].

Exterminators who use pesticides Exterminators, who apply pesticides and control termites at residential areas and public places, are another major group of workers who can get exposed to organophosphates [36]. A survey on pesticide applicators who had worked for a median of 1.8 years applying organophosphates against termites and other pests in the state of North Carolina, USA, showed that the average

urinary chlorpyrifos metabolite of the recently exposed applicators (629.5 mg/L) was far higher than that of the general population in USA (4.5 mg/L) [37].

Greenhouse workers and florists Pesticide exposure is also known among the greenhouse workers and florists. Their work includes the use of pesticides on flowers, other plants, and foliage. Fumigant pesticides can be a cause of potential health risk to the employees of greenhouses [31].

3.1.2 Non Occupational Exposure

Environmental or non-occupational exposure to pesticides in individuals occurs in places where the exposure to pesticides is not a result of the occupation [38]. A number of the non-occupational exposure situations are briefly discussed in the following sections.

Residential exposure Domestic use of pesticides is common among the urban and rural dwellers. A report states that 80 to 90 per cent of USA households use pesticides for various applications [39]. Organophosphate insecticides are used for killing bugs in and around the house and in the garden where exposure to organophosphate can easily occur [40].

Close proximity to agricultural farms Exposure can often occur when pesticides applied at agricultural farms drift to surrounding areas where general people live. This form of exposure is known as the "farm proximity pathway" [33]. The nearby residents' exposure may not be as acute as it is among agricultural workers; however, their proximity to an organophosphate source still puts them at risk.

Aerial spraying The extensive spraying of pesticides from aircraft over residential areas can be a source of exposure in the general population, if the residents of the sprayed areas breathe in the air that contains airborne pesticides [32].

Exposure in public places Exposure to pesticides in public places is an unexpected, unintentional, non-occupational form of exposure [36]. For example, people can be exposed to organophosphate insecticides applied by exterminators in common places like public restrooms, restaurants, hotels, schools, churches, business offices, apartment buildings, grocery stores, and hospitals.

Pesticides in food and water Pesticide residues can be found in fruits, vegetables, and other crops due to the irrational use of pesticides during cultivation. Agricultural washed water containing pesticide residues may enter into water streams close to the agricultural fields, and eventually the pesticide residue may affect fishes and other living organism in the water reservoir [41]. It is reported that the pesticide residue concentration found in food and water bodies is low, however, regular accumulation in human body, especially when it exceeds the Maximum Residual Level (MRL), may cause harm to human body [42].

3.2 Intentional Exposure

Under exceptional circumstances, such as committing suicide, individuals may expose themselves to pesticides intentionally. The main route of exposure is ingestion [4]. The victims may use pesticides to harm themselves because of the availability of pesticides. Often farmers keep their own supply of pesticides, commonly within, or close to, the households which makes an easy access to pesticides for other people [43]. In some cases, the damage caused by the pesticides to human body is fast and irreversible, which allows very limited time to rescue the victim exposed to pesticides (e.g. parathion). Thus the occurrence of fatal intentional exposures increases.

The pattern of using pesticide is also an important issue. When two or more pesticides used simultaneously, they become more toxic (e.g. heptachlor and lindane) or less toxic (antagonism) [4]. Interactions of dietary nitrite with pesticides that contains secondary amine group can result in the formation of nitrosamines, which may be more toxic, mutagenic, or carcinogenic [44].

4 Effects of Pesticides on Human Health

The toxic effects of pesticides on human health can be of various forms, such as: headache, coma, and convulsions to even death [45]. While some of the effects are irreversible, others can be made reversible in long term. The effects of pesticides can be cured with prompt medical treatment. However, based on the degree of toxicity, the effects on human health can be broadly classified into two groups: acute or short term effects, and chronic or long term effects.

4.1 Acute or Short Term Effects

"Acute effects" of pesticides on human health can be defined as *the harmful effects that occur from a single exposure by any route of entry*. The exposure to acute toxicity can occur through different routes such as: dermal (skin), inhalation (lungs), oral (mouth), and eyes [45]. The principle toxic effect is the inhibition of cholinesterases in the blood and nervous system, which prevents degradation of acetylcholine at the neuronal synapses, resulting over activity of the cholinergic neurons [46].

Some acute and sub-acute toxic effects include irritation, burning, stinging and itching, rashes and blisters on the nose, throat, and skin, nausea, dizziness, diarrhea, headache, impaired cognition, blurred vision, proximal muscle weakness, and seizures. The initial symptoms may not be severe enough to seek for immediate medical attention for an individual. However, treatments should be prescribed if someone is exposed to pesticides [47].

Acute toxicity is determined by examining the dermal toxicity, inhalation toxicity, oral and eye toxicity, and skin irritation under controlled laboratory conditions. The laboratory test is often based on measuring the amount of pesticide required to kill 50 percent of the animals in a test population, which is expressed in terms of LD_{50} (lethal dose 50) or the LC_{50} (lethal concentration 50). The LD_{50} and LC_{50} values are determined based on a single dosage and are recorded in milligrams of pesticide per kilogram of body weight (mg/kg) of the test animal or in parts per million (ppm). LD_{50} and LC_{50} values are useful in comparing the toxicities of different active ingredients and different formulations containing the same active ingredient. The lower the LD_{50} or LC_{50} value of a pesticide product, the greater its toxicity to humans and animals [45].

4.2 Chronic or Long Term Effects

Any harmful effect that occurs from small doses repeated over a period of time is termed as "chronic effects". Chronic effects of pesticides may not appear for weeks, months, or even years after exposure; but later, when it starts showing its impacts, it becomes difficult to connect relevant health impacts to pesticides exposure [47]. The chronic toxicity of a pesticide is more difficult to determine than acute toxicity analysis. LOEC (lowest observed effect concentration), NOEC (no observed effect concentration), and EC_{50} (half maximum effective concentration) are some of the approaches for measuring chronic toxicity. Chronic health effects due to pesticide exposure include neurologic, carcinogenic, pulmonary, and reproductive effects.

4.2.1 Neurologic Effects

From recent studies it is becoming increasingly apparent that chronic occupational exposure to a variety of pesticides can cause mild to severe deterioration in neurologic function that may be irreversible [48]. Chronic neurologic effects have been associated with exposures to organophosphate, organochlorine, and carbamate insecticides, a variety of fungicides (such as: tnercurials, diphenyl, hexachlorobenzene, hexachlorophene) and fumigants (such as: methyl bromide, carbon disulfide, sulfuryl fluoride) [48]. Agricultural workers are the primary victims of these effects since these pesticides are used in agricultural purposes. The commonly reported chronic neurological effects include lethargy, fatigue, headache, hyperirritability, dizziness, muscle tremor, twitching, jerks, weakness, paralysis, paresthesias, polvneuropathy, incoordination, visual disturbance, central nervous system impairment, loss of memory, forgetfulness, confusion, altered sleep, slurred speech, impaired motor skill, altered behavior, nervousness, psychiatric symptoms, nervousness, agitation, and Parkinson like syndrome [46].

4.2.2 Carcinogenic Effects

Several studies have shown that exposure to pesticides may impose a potentially serious cancer risk to the general population [49]. Types of cancer that are associated with pesticides exposure include soft tissue sarcoma and lymphoma, non-Hodgin's lymphoma, soft tissue sarcoma leukemia, lung carcinoma, and ovarian carcinoma. A survey conducted by the National Toxic Forum reported that 28 out of 47 pesticides are suspected as being carcinogenic [49]. In addition, cancer related to hematopoietic system have been observed among workers with significant pesticide exposures [50]. However, the available data are insufficient to estimate the rate of pesticide-related cancer for the general population [50].

4.2.3 Pulmonary Effects

Chronic respiratory impairment has been found in workers with many years of exposure to organochlorine and organophosphate insecticides. Some of the pulmonary effects are persistent pulmonary fibrosis, chronic cough, and bronchiolitis obliterans. [51].

4.2.4 Reproductive and Developmental Effects

Many pesticides are known to have reproductive effects [47]. Agricultural workers appear to be associated with specific morphologic abnormalities in sperm. Several studies suggest that parental employment in agriculture could increase the risk of congenital malformations in offsprings, particularly orofacial cleft. Miscarriage, infant prematurity, and congenital malformations have been detected in female floriculture workers exposed to pesticides. [52].

4.3 Health Condition of Individuals

The impact of pesticides may vary with health condition of the affected person. It has been seen that children are more vulnerable to immunological, developmental, and neurological symptoms from pesticides than adults. The higher rate of cell division, respiration, and developing organs, nervous and immune systems of the children increase their susceptibility to pesticides attack [52]. In particular, exposure to neurotoxins at levels that would be safe for adults may cause permanent loss of brain function in infants and toddlers. Certain pesticides, such as pyrethrin/pyrethroid, organophosphate, and carbamate may severely affect asthma patiens [53].

5 Recommendations

The key reasons behind the health effects caused by pesticides are the lack of proper knowledge and awareness of pesticide use, absence of legislative enforcement, and uncontrolled sale of toxic pesticides in open markets [4]. Compliance with available standard guidelines for the safe use of pesticides, and cautious measures during selling and storing pesticides can minimize most of the hazards related to pesticide exposure.

5.1 Measures During Selling

The manufacturer, the formulator, or the person responsible for labeling and registering the pesticides with national authority should ensure proper labelling written in local language with comprehensive instructions for safe use, and warning for possible hazards. The label should additionally specify the ingredients, and also provide instructions for first aid in case of poisoning [4].

5.2 Measures During Applying Pesticides

Users should follow the instructions provided in the label of the container or packaging before using pesticides. The users and producers should use personal protective equipment, such as protective clothing made of butyl rubber, PVC, neoprene, laminated poly ethylene fabrics, gloves, eye protectors and masks to prevent the risk of personal hazard [54].

5.2.1 Pesticides Applied in Agriculture

The Integrated Crop Management (ICM) includes guidelines to be followed by the farmer unions to enforce actions for the production of safe agricultural products without contaminating the environment [55]. For pest control, the ICM encourages the use of complementary methods of pest management to reduce animal pests or weed population below its economic injury level, and to minimize pesticide impacts on the other components of the agro-ecosystem. Pest resistant crops against insects and fungi, biological control, and other cultural or physical measures can be used as complementary methods. Pesticide applications on crops should include the following information [55]:

(a) identify the appropriate pesticide for the specific pest attack the plants or crops,
(b) use of pesticide at the recommended dose when a pest is found or it requires a precautionary treatment,

(c) optimization of pesticide use for economic saving through adjusted doses according to pest population density, and
(d) minimization of pesticide use by altering the cultivation system to lower the risk of pests.

To ensure the safety of agricultural workers, pesticide handlers and cultivators, US EPA activated the Worker Protection on Standard (WPS) in 1995 [56]. The aim of the WPS regulation is to "minimize pesticide exposure, mitigate the exposure that occur and inform agricultural workers about the hazards of pesticides". It requires the agricultural employers to notify the workers about the pesticide treatments and advances. WPS also offers basic pesticides training, provides personal protective equipment, and supplies the affected worker and medical personnel with proper information [56].

5.2.2 Pesticides Applied at Home and Work Place

According to a study conducted by EPA, around 85% of the total daily exposure to airborne pesticides comes from breathing air inside the home [57]. Improper pesticides applications should be avoided at homes and offices. For any pest related issue, alternative measures, such as temperature treatment, biological controls, and least toxic baits should be applied. Spraying pesticides in lawns and gardens should be avoided [57].

5.3 Measures After Pesticides Poisoning

The chemicals of pesticides may injure humans in many ways. It is therefore, important to take appropriate measures if pesticide poisoning or exposure occurs beyond the permitted limits. In case of any pesticides poisoning, could occur, the following steps may be followed [58–61].

Seek for medical assistance In any pesticide poisoning, the first thing is to avoid further contamination, and to ensure that the victim is breathing. There is a good chance of recovery if proper oxygen supply to the body can be maintained. Following this, medical assistance should be sought [58].

Measures during direct pesticides exposure Emergency treatments depend on type of exposure. It has been mentioned before that pesticides can enter in our body in one of three route of exposure: dermal (absorption through the skin or eyes); respiratory (inhalation through the lungs); or oral (ingestion by mouth). Measures during any kind of exposure are discussed below:

(a) **Measures in case of swallowing pesticides:** If someone swallows pesticides, the victim should be treated immediately. Firstly, the label of pesticides has to be identified. There are two ways that can be used to help out the victim in case

of swallowing poison: either (1) inducing vomiting or (2) diluting the poison by having the victim drink milk or water [59].

Inducing vomiting is the quickest way to get the pesticides out of stomach, however, it may not be effective in certain cases like

- when the victim is unconscious
- when the pesticides is highly corrosive or highly concentrated petroleum product.

(b) **Measures when skin and eyes get exposed to pesticides:** If the skin directly get exposed to pesticides, it is advised to wash off the pesticides immediately to prevent further exposure and followed by drenching the skin with soap and water carefully. In case of chemical burning, cold running water should be used to wash the skin. The affected area then need to be covered loosely with clean soft clothes. Further treatment should be carried out based on medical advisory [60].

In case of eye injury, eyes should be washed with clean water immediately for around 15 min since eye membrane can absorb pesticides faster than any other external part of the body. Eye lids should be kept open while washing with a gentle stream water and using any kind of drugs or eye drops are prohibited [58, 61].

(c) **Measures in case of inhaling pesticide:** The victim need to take fresh air immediately after inhaling pesticides. Artificial respirator should be used while shifting the victim, and also when the victim suffers from breathlessness. Victim should be kept as quiet as possible. Tight clothing should be loosened. If the victim is getting unconscious, he should be protected from getting fall and his chin should be pulled forward to ensure proper air flow [58, 60].

5.4 Development of Techniques for Exposure Assessments

Bio-markers are of great importance in case of determining any biological action of pesticides, like DNA or RNA damage or any change of gene expressions, which are eventually related to the exposure to pesticides. Extensive research should be conducted to develop reliable bio-markers as predictors of subsequent health outcomes. Besides, studies should be continued to improve the existing methods of exposure assessment, and to reduce the health risk from pesticides poisoning [52].

6 Conclusion

Pesticides play an important role in producing reliable supplies of agricultural produce at affordable prices to consumers, improving the quality of produce, and ensuring high profits to farmers. Although pesticides are developed to function with reasonable certainty and minimal risk to human health and the environment, many

studies have raised concerns about health risks from occupational and non-occupational exposures to pesticides and pesticide residues. The overall optimization of pesticide handling by following the existing regulations could contribute to the reduction of the adverse effects of pesticides on human health and the environment [62].

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