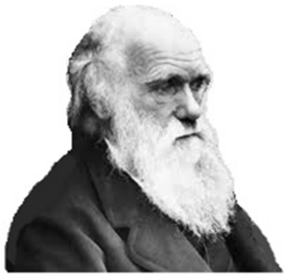
Available online at www.worldnewsnaturalsciences.com



World News of Natural Sciences

An International Scientific Journal

WNOFNS 44 (2022) 192-214 EISSN 2543-5426

# Effect of pesticide residue in food crops on man and his environment

**Chizoba Victory Obunadike[1,*], Yussif Yunusah Yakubu[2], Opeyemi Olabode Abdulrazaq[1], Ayomide Oluwaseyi Ogunsanmi[3], Zahradeen Muhammad[4], Waheed Sakariyau Adio[5], Isah Abdulshakur Lawal[4], Azeez Soliu Adisa[5]**

[1]Department of Pure and Applied Chemistry, Faculty of Basic and Applied Sciences, Osun State University, Osogbo, Osun State, Nigeria

[2]Department of Chemical Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ashanti Region, Ghana

[3]Department of Biochemistry, Faculty of Pure and Applied Sciences, Kwara State University, Malete, Kwara State, Nigeria

[4]Department of Pure and Applied Chemistry, Faculty of Science, Kaduna State University, Kaduna, Kaduna State, Nigeria

[5]Department of Biochemistry, Federal University of Technology Minna, Niger State, Nigeria

*E-mail address: obunadikechizoba1234@gmail.com

**ABSTRACT**

The use of pesticides has been a catalyst that improves crop quality and yield. It can be designed using conventional or modern technologies depending on the type of pesticides being used. It is used to prevent organisms that are considered to be harmful to crop growth and development by protecting them from pests and diseases, thus increasing food crop’s quality. There are several classifications of pesticides among which are; insecticides, fungicides, rodenticides, etc. Physicochemical and biological methods are the basic two ways of detecting pesticide poisoning. Immunoassays (biological) are the most prominent methods of detection, it requires the use of fluorescent, chemiluminescent or other detection methods to detect drugs, proteins, and some hormones. Pesticide residues are responsible for environmental pollution such as groundwater contamination, global warming and killing non-target organisms in the soil. Exposing the human body to excess pesticide residue can lead to various severe health conditions such as cancer, asthma, etc. The metabolism of pesticides in the body system undergoes two stages, namely; phase one and phase two. oxidation reactions occur in phrase one

( Received 24 July 2022; Accepted 17 August 2022; Date of Publication 18 August 2022 )

whereby pesticides functional groups are majorly synthesized by Cytochrome P450 enzymes. Phase two includes the reactions of phase I substrate with glucuronic acid ($C_6H_{10}O_7$), tetraoxosulphate(VI) acid ($H_2SO_4$), ethanoic acid ($CH_3COOH$), etc. to form more polar compounds for easy excretion. The introduction of inexpensive biodegradable pesticides and the enforcement and implementation of pesticide control and regulation laws has helped to decrease the negative effects of pesticide residue in humans and the surroundings. Pesticide residue can be eliminated or reduced from food crops by practicing organic farming, washing, and food product processing, natural pesticide application, and rational use of pesticides. It is highly recommended to follow the prescription of pesticides used to avoid its toxicity in the biological systems.

***Keyword*:** food crops, pesticides, effect, environmental pollution

## 1. INTRODUCTION

Pesticides application in agriculture is a cheap method used to prevent different pests, although they are referred as one of main pollutants in our surroundings. According to estimates from the World Health Organization (WHO, 2005) and United Nations Environmental Program (Pimental et al., 1992), there are between one and five million cases of pesticide poisoning among agricultural workers each year, with about 20,000 fatalities occurring in developing countries. Pesticide definition is quite numerous; it is defined as a substances which halt, terminate, or prevent food pests during production, processing, storage, or marketing processes in agriculture, according to the Food and Agriculture Organization (FAO) (FAO, 1986). Pesticides are required to meet the rapidly rising human needs (food, cotton fiber, tobacco, etc.) and to control vector-borne diseases.

However, during agricultural practices, these compounds are released into the environment and affect the living organisms (plants, animals, and humans) in a diversity of medium which includes skin contact, inhalation of fumes, ingestion of food, and drinking. Crops can benefit from pesticides, but they also have negative effects. Impurities in ostensibly inert compounds such as solvents, wetting agents, and emulsifiers aggravate it negative effect on public health (Hashmi and Dilshad, 2011).

These compounds are prevalent in the household, are difficult for the clan to manage, and are unevenly disseminated through racial and socioeconomic categories is the underlying resemblance between lead exposure in poor children and exposing farmer's children to pesticide residue. Compare to lead, less is known about the potential developmental effects of pesticide exposure throughout childhood. Several pesticides caused behavioral effects on mice (Icenogle et al., 2004).

Despite the lack of proper investigation on how pesticide affect the human neurobehavioral development, however children exposure to pesticides is of great concern. First, cholinesterase is inhibited by carbamates and organophosphates, two extensively used insecticide families.

Cholinesterase inhibition leads in an overabundance of acetylcholine at synapses, which then over activates cholinergic circuits in the brain. There is evidence that pesticides such as organophosphates and carbamates can affect cholinesterase-mediated gene signaling in the developing mouse brain as well as induce faulty brain wiring through various channels (Slotkin, 1999; Aldridge et al., 2005; Sallam et al., 2006, 2009 a,b).

## 2. DEFINITION OF PESTICIDES/PESTICIDE RESIDUES

Pesticides are pest control agents (EPA, 2018). Pesticide residues, on the other hand, are pesticides that can be found on or in food after they have been sprayed on food crops. Pesticides include herbicides, insecticides, termiticides, nematicides, molluscicides, avicides, rodenticides, bactericides, antimicrobials, fungicides and insect and animal repellents (Randall et al., 2014). Herbicides accounts for eighty percent pesticide use in agriculture. A substance or mixture of substances was defined as a pesticide if it was intended to prevent, eradicate, or control any pest, including those that could spread human or animal disease, are undesirable plant or animal species, cause harm during the production, processing, storage, transport, or marketing of food, agricultural products, wood and wood products, or are substances that could cause cancer or reproductive harm." This term refers to compounds that are intended to be used as a desiccant, defoliant, or fruit thinning agents or enhancing food maturity and prevent decomposition when stored and transported (FAO, 2002).

### Historical Background of Pesticides

Insecticides have been used to protect crops since before 2000 BC. Sulfur dust was used as the first known pesticide four thousand five hundred years ago in Iraq. The knowledge of verses book, which dates back around 4,000 years, discusses the application of deadly herbs to eliminate pests (Rao et al., 2007). To eliminate pests, crops were sprayed with toxic compounds in the middle ages. Nicotine sulfate were produced in the 17th century using Tobacco leaves, these compound was an effective and efficient pest control agent. Two more organic pesticides were developed in the nineteenth century: rostenone, derived from the roots of tropical plants, and pyrethrum, derived from chrysanthemums (Miller, 2002). Arsenic-based pesticides were the norm until the 1950s (Ritter,2009). DDT is a highly effective insecticide, according to Paul Müller. In United States, organophosphates and carbamates was a substitute for DDT in 1975. Pyrethrin-based pesticides have since become the most widely used (Ritter, 2009). In the 1960s, glyphosate, alkanoic acids like 2,4-dichlorophenoxyacetic acid, and nitrogen-based chemicals like Triazine were the most widely used herbicides (Ritter, 2009). The first federal pesticide regulation law was passed in 1910 (Goldman, 2007), but it wasn't until the 1940s that their use really took off (Daly et al., 1998).

According to some, the "pesticide era" began in the 1940s and 1950s (Murphy, 2005). Even though the Environmental Protection Agency was founded in 1970 and the pesticide legislation was changed in 1972 as a result, 2.3 million tonnes (2.5 million short tons) of commercial chemicals are still used annually in farming activities (Goldman, 2007). Pesticide use has increased by a factor of 50 since 1950. (Miller,2002). Despite the fact that wealthy countries consume 75% of the world's pesticides, pesticide consumption is increasing in poorer countries (Miller, 2004). A research of pesticide uses in the US from 1997 to 2003 was published by the National Science Foundation's Center for Management in 2003. Ritter (2009) and Aspelin (2003) DDT was determined to be a major threat to biodiversity in the 1960s by preventing the reproduction of a large number of fish-eating birds. Silent Spring, Rachel Carson's best-selling book, investigates biological magnification because of the Stockholm Convention on Persistent Organic Pollutants, DDT is no longer used in agriculture. Nevertheless, it is used in a small number of developing nations to prevent the spread of malaria and other tropical diseases by dusting poison or pesticides throughout the house (Lobe, 2006).

**Types of Pesticides**

Pesticides are grouped based on the following: intended species (e.g., rodent, insect, fungi, and pedicule; Gilden et al., 2010); chemical compositions (e.g., organic, inorganic, synthetic, or biological (bio-pesticide); but the lines between these categories are occasionally muddled; and physiological state (e.g., gaseous); (fumigant). Examples of bio-pesticides include microbiological insecticides and biochemical pesticides (EPA, 2017). Insecticides made from plants, or "botanicals," have developed swiftly. They include neonicotinoids, rotenoids, pyrethroids, and a fourth category that consists of strychnine and scilliroside (Kamrin, 1997). Chemical families are used to categorize pesticides. Organochlorine, organophosphate, and carbamate pesticide families are all well-known. Organochlorine hydrocarbons, such as DDT, may be converted into other chemicals such as dichloro diphenyl ethane and cyclodiene compounds. They compel the neuron to communicate constantly by altering the sodium/potassium balance of the nerve fiber. These compounds toxicity varies greatly, but due to the persistence and bioaccumulation potential, they have been phased out (Kamrin, 1997). Organophosphates and carbamates have essentially replaced organochlorines as a result of their ability to inhibit the enzyme acetylcholinesterase, which allows acetylcholine to continue sending nerve impulses and cause a variety of symptoms like paralysis and weakness. Organophosphates are extremely lethal to vertebrates, and in some circumstances, less hazardous carbamates have taken their place (Kamrin, 1997).

**Table 1.** Various Pesticides Depending on the Target Organism

| Types | Target Pests | Actions |
|---|---|---|
| Algicide | Algae | Controls the growth of algae in pools, canals and water tanks |
| Avicide | Birds | Control birds that destroy farm crops |
| Bactericide | Bacteria | Kill microorganisms such as bacteria |
| Fungicide | Fungi | Kill fungi (blights, mildews, molds) |
| Herbicide | Plants | Prevent growth of weeds and other unwanted crops |
| Insecticide | Insects | Kills and prevent insects and other arthropods from feeding on food crops |
| Miticide | Mites | Eliminate and prevent mites which feeds on plants and animals |
| Molluscicide | Snails | Eliminate and prevent snails and slugs |
| Nematicide | Nematodes | Eliminate and prevent nematodes (warm-like organisms) |
| Rodenticide | Rodents | Eliminate and prevent mice and other rodents |
| Virucides | Viruses | Eliminate and prevent different forms of viral organisms |

**Types of Pesticides**

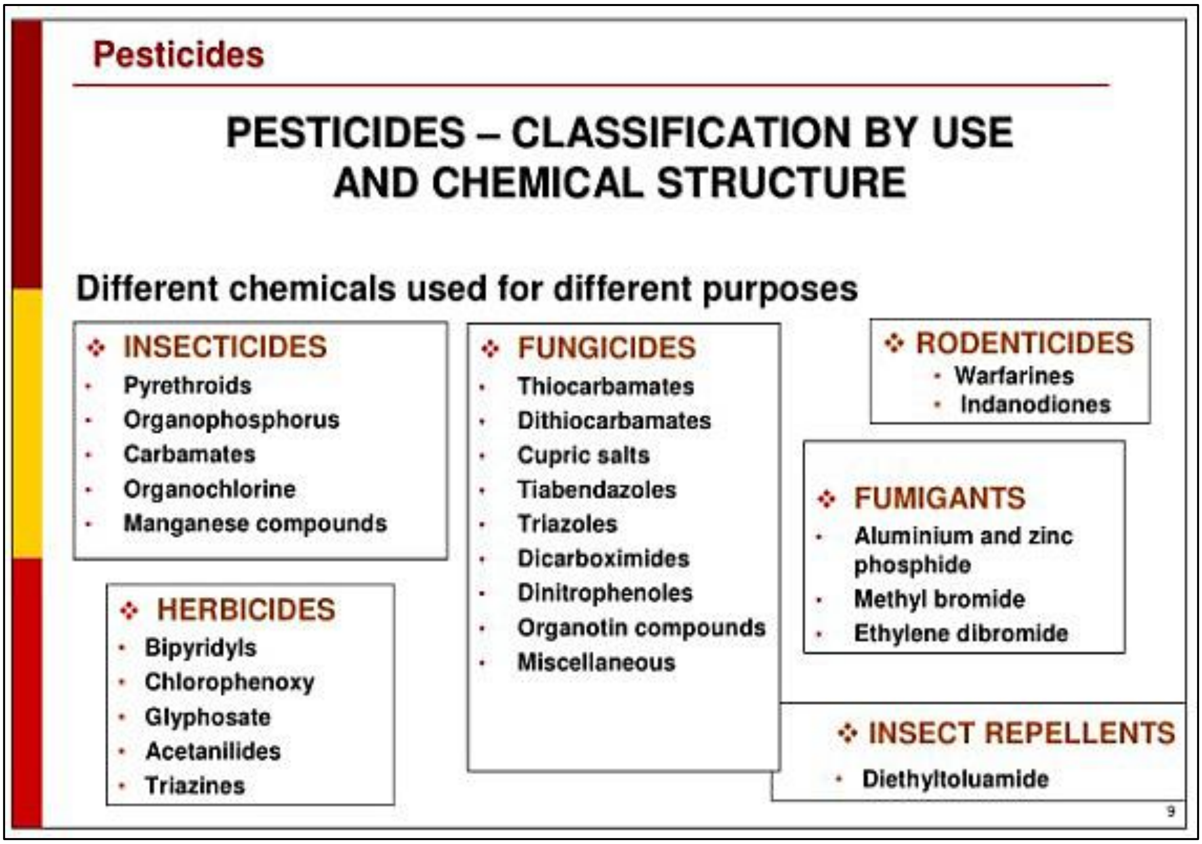



**Figure 1.** Types of pesticides based on chemical structure and uses

In many cases, the name of a pesticide depends on the kind of pest it kills. Pesticides can also be grouped using the time and medium of degradation. For example, DDT's persistence allowed it to accumulate in the food chain and kill top predatory birds. For a different perspective on pesticides, consider how chemical pesticides affect the ecosystem and it source or manufacturing process (EPA,2013).

**Insecticides**

Neonicotinoids are neuroactive insecticides that is related to nicotine chemically. Imidacloprid, a member of the neonicotinoid family, is a vastly applied insecticide globally (Yamamoto, 1999). In the late 1990s, environmental impacts of neonicotinoids were greatly studied and it result showed quite a number of negative ecological effects such as colony collapse disorder (CCD) and bird population declines caused by insect population declines. The use of many neonicotinoids was restricted in 2013 by the European Union and some non-European Union countries. Dick (2013), Cressey (2013), Gill et al. (2012), Stoddart (2012), and Osbrone (2012) (2012) By interfering with the function of acetyl cholinesterase, which controls the amount of acetylcholine at nerve synapses, insecticides, carbamates, and organophosphates have an adverse effect on the neurological system of their target animals (and non-target creatures). As a result of this inhibition, the parasympathetic nervous system is overstimulated and synaptic acetylcholine levels are increased (Colovic et al., 2013). Most of these pesticides were created in the middle of the 20th century and are very dangerous. Despite being widely used in the past, other chemicals (including DDT, chlordane, and toxaphene) are no longer sold on the market because of their detrimental effects on human health and the environment (Public Health Statement, 2002; Medical Management Guidelines, 2012). As a synthetic substitute for the naturally occurring pyrethrin, which comes from chrysanthemums, the environmental stability of pyrethroid insecticides has been enhanced. Some synthetic pyrethroids can cause nervous system cancer (Soderlund,2010).

**Herbicides**

Along with terbacil (Appleby et al., 2002), nicosulfuron, flazasulfuron, metsulfuron-methyl, rimsulfuron, sulfometuron-methyl, and trifluorosulfuron-methyl, sulfonylureas are often employed to control weeds. These broad-spectrum herbicides work by inhibiting the acetolactate synthase enzyme to kill weeds, plants, and insects. Crop boosting chemicals were regularly administered at rates above 1 kg/ha (0.89 lb/acre) between 1960 and 1969, although sulfonylureates only need 1% material to get the same impact (Lambert et al.,2013).

**Biopesticides**

Biopesticides can be defined as the group of insecticides derived biological organisms which includes plants, animals, bacteria, and minerals. There are three classifications namely microbial pesticides, biochemical pesticides and herbal pesticides

**Microbial pesticides**

Microbial pesticides are pesticides made from micro-organisms such as bacteria, fungi, or viruses or metabolites secreted by fungi or bacteria. Entomopathogenic nematodes, despite being multicellular also fall into this category (Coombs, 2013; Borgioetal, 2011).

**Biochemical pesticides** or **herbal pesticides** (Pal, 2013)

Insect pests and microbiological illnesses can be controlled naturally with biochemical and herbal insecticides (Pal, 2013). The genetic composition of plant-incorporated protectants (PIPs) include genetic material from several species (i.e. GM crops). Its use in agriculture is debatable, particularly in first-world nations (Plant In corporated Protectants, 2018).

**Uses of Pesticides**

To get rid of potentially hazardous organisms, pesticides are utilized (Whitford, 2009). For instance, they are used to get rid of mosquitoes that could spread diseases including malaria, yellow fever, and the potentially fatal West Nile virus. They can also get rid of ants, wasps, and bees that could cause allergic reactions. Insecticides help shield animals from diseases spread by parasites like fleas (Whitford, 2009). Human sickness that can be caused by tainted fruit or moldy food can be prevented by pesticides. Trees, brush, and weeds that grow next to the road can be eliminated with herbicides. They cause death and could damage the ecosystem.

Herbicides are widely used in lakes and ponds to control the growth of algae and other plants, like water grasses which prevent fishing and swimming and give the water an unpleasant appearance or smell (Helfrich et al., 1996). Termites and mold are uncontrollable pests that can damage homes and other buildings (Whitford, 2009). In food storage facilities and market, insecticides are used to prevent rodents and insects which can contaminate food, such as yam, cassava and grains.

Whenever pesticide is used on in agricultural practices risk is inevitable. When the dangers associated with pesticide usage are reduced, regulatory bodies for pesticides like the Canadian Pest Management Regulatory Agency (PMRA) and the United States Environmental Protection Agency (EPA) declare them acceptable. Since the 1950s, DDT, an organochlorine, has been sprayed on home walls to prevent malaria. In recent policy announcements, the World Health Organization reiterated its support for this method (W HO, 2007). However, due to its toxicity to humans and permanence in the environment, DDT and other organochlorine pesticides have been outlawed internationally. Because 19 mosquito species had acquired a resistance to DDT by 1972, after it was originally found in Africa in 1955, its usage is not always effective. (WHO, 2000).

**Dispersion Pesticides into Human Body**

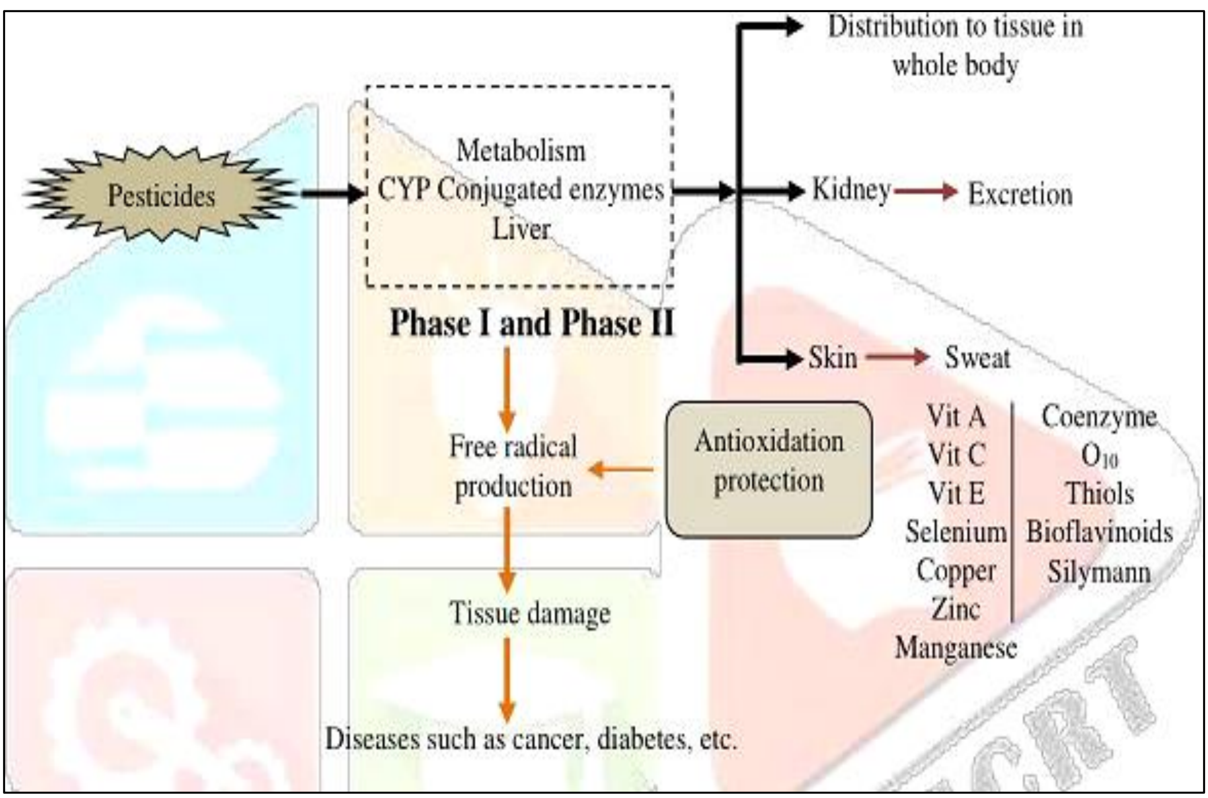



**Figure 2.** Pesticides Detoxification Pathway (Rose et al., 2004)

The skin, mouth, and lungs are the three mechanisms via which pesticides can harm a human organism (Figure 2). Whether a chemical is a solid, liquid, or gas, determines how likely it is that it will enter the body (Berthet et al., 2014). Compared to liquid or gas products, which can enter the body through any of the three entrance sites, solids normally have a lesser possibility of entering the body through the lungs. However, if solid pesticide particles are tiny enough or remain on the skin for long enough, the same mechanisms by which liquids or gases enter the body can also apply to them. The most frequent way for casual users to become poisoned by pesticides is through skin absorption (Marcfarlane et al., 2013). Dermal absorption may occur as a result of splashes and spills while handling pesticides (mixing, loading, or disposing of them).

Exposure to high residual loads may, to a lesser extent, result in dermal absorption. The toxicity of the pesticide to the skin, the duration of exposure, the pesticide's composition, and the body part contaminated determine the amount of danger from dermal absorption (Baldi et al., 2006). Powdered, finely ground, and granular pesticides do not penetrate the skin and other human tissues as fast as liquid formulations do. On the other hand, liquid pesticides that contain solvents (such organic solvents) and pesticides based on oil are often absorbed more quickly than dry pesticides. For instance, emulsifiable concentrates, which contain a sizable amount of the hazardous substance in a negligibly large amount of solvent, are readily absorbed by the skin. Some bodily areas are more likely than others to absorb pesticides.

**Pesticides poisoning**

The agrochemical industry has provided thousands of chemicals. The climate in Pakistan favors insect growth, which results in the death of about 20% of potential agricultural crops. The irrational use of pesticides poses substantial dangers to the health of agricultural managers and farmers in particular. In comparison to insecticides, the organophosphate and carbamate families are more significant in terms of the immediate and long-term impacts they have on human health. These herbicides inhibit cholinesterase, an enzyme necessary for the neurological system to operate normally (Travisi and Nijkamp, 1998; Gelman and Hill, 2007; Soares and Porto,2012).

**Acute toxicity**

By phosphorylating and inhibiting the enzymes A ChE, organophosphorous chemicals induce significant systemic damage. Pesticides fuse to cholinesterase and stop acetylcholine and acetic acid from being broken down at the postsynaptic junction without affecting acetylcholinesterase, causing acetylcholine to build up (Chan and Critchley, 1998; Mason, 2000). The symptoms of OP-induced neuronal damage are produced by axonal death. The neuropathy targetesterase is suppressed after exposure to OPs, and many of these effects are permanent.

**Methods of Detecting Pesticides**

There are numerous approaches available to determine potential pesticide exposure. Anamnesis, physical examination, clinical sign evaluation, diagnostic and toxicological analysis are some of the general processes used when recognition is required because a patient who was seen in the hospital had been poisoned. It is typically essential to gather a specimen and test for the pesticides and/or metabolites present in the tissues such as blood, liver, stomach and the surrounding, the inquiry aims to measure a potential pesticide (air, water, ground). The analysis's goal will determine which test is used. It is also crucial to take a method's financial costs into account. Simpler tests are crucial for reliable analysis since they are affordable and have special qualities such high sensitivity, specificity, precision, and accuracy. (Narsico et al., 2009; Niessen et al., 2012).

## Physicochemical methods

Techniques for physical-chemical separation comprise of capillary electrophoresis (CE), liquid chromatography (LC), and gas chromatography (GC): Since it offers better resolution and lower detection limits, GC is still the method utilized when the tested pesticide is volatile or semi-volatile. The characteristics of the particular analytes will often influence the detector choice for GC. The sample is volatilized before being introduced into a chromatographic column that has been packed or coated with a solid or liquid stationary phase, which forms the basis of gas chromatography. A gaseous mobile phase that is inert and has no interaction with the analyte elutes the analyte. Depending on the detector, the carrier gases should be both pure and chemically inert. The most common carrier gases are hydrogen, helium, argon, nitrogen, carbon dioxide, and carbon monoxide (Skoog et al., 1992).

LC has developed into a very powerful separation technique. This technique may successfully distinguish nonvolatile and thermally unstable pesticides that are incompatible with GC. In LC, extracts are run through a variety of adsorbent columns that can tell the target analyte from the components of the matrix. The degree of selectivity will depend on the adsorbent in the column—alumina, silica gel, or Florisil—mesh size, and activity levels. Columns can be used separately or in combination **(**Andreu et al., 2012).

CE is a practical technique for isolating and classifying a range of chemicals. EC offers excellent separation efficiency and high resolution. As a result of the reduced sample size and minimal solvent usage, analysis is completed more quickly and at a lower cost (Assuncao et al., 2008). In an ideal detector, the response to changing analyte concentrations would be linear, with adequate sensitivity, acceptable stability, and repeatability. It should also be simple to operate, temperature-flexible, and have a short reaction time (independent of flow).

## Biological methods

Environmental pollution is frequently monitored through chemical analysis of isolated substances, although such investigations can be expensive, have a limited scope, and cannot reveal biological impacts. On the other hand, biological tests show the toxicity of a variety of compounds or environmental samples, making them essential for identifying the impact of these chemicals' presence on the environment (Oliveira et al., 2012). The biological component is addressed by approaches such as biosensors and immunoassays. Immunoassay, one of the most used analytical methods, is a powerful instrument in clinical labs. Here, commercially available immunoassay instruments and kits depend on fluorescent, chemiluminescent, or other detection methods. A number of samples, including natural water, food, and blood, as well as a variety of compounds, including medications, proteins, and hormones, can be used in immunoassays to detect and measure the presence of pesticide residues (Andreu et al., 2012).

## Food Crops

Crop can be defined as plant or animal product that can be widely cultivated and harvested for income or dietary needs (www.merriam- webster.com). Crops can refer to the entire harvest or to the harvest after it has been processed more thoroughly. The majority of crops are grown in aquaculture or agriculture. Macroscopic fungus (like mushrooms) or alga are examples of crops. The majority of crops are collected for human consumption or as animal feed. Crops can be foraged in the wilderness. Horticulture, floriculture, and industrial crops are crucial non-food crops. Plants utilized for other crops are considered horticulture crops. Bedding plants, indoor plants, flowering plants for gardens and pots, cut cultivated greens, and cut flowers are all crops used in floristry. Clothing, biofuel, and medicine are all examples of industrial crops (medicinal plants).

**Figure 3.** Diagram of Various Food Crops

### Important of food crops

The value of a crop varies widely by region, from supplying daily energy needs to healing damaged tissues and bolstering the immune system. The crops that contribute the most to the world's supply of food for people are as follows (2013 numbers for kcal/person/day are provided in parenthesis): Rice (541 calories), wheat (527 calories), sugarcane and other sugar crops (200 calories), maize (corn) (147 calories), soybean oil (82 calories), other vegetables (74 calories), potatoes (64 calories), palm oil (52 calories), cassava (37 calories), legume pulses (37 calories), sunflower seeds (35 calories), rape and mustard oil (34 calories), other fruits (31 calories), sorghum (28 calories), millet (27 calories), groundnuts (25 calories), beans ( (FAO, 2017). Keep in mind that many crops that appear to be small internationally are actually quite important locally. For instance, in Africa, roots and tubers account for the majority of daily energy intake (421 kcal), with sorghum and millet providing 135 kcal and 90 kcal, respectively (FAO, 2017).

### Alternatives to Pesticides

Genetic engineering, biological pest controls including pheromones and microbial pesticides, and methods to stop insect reproduction can all be used in cultivation (Miller, 2004). Additionally, pest control has been achieved by using composted yard waste (Mosorley et al., 1996). These methods are becoming more and more popular and are frequently preferred over common chemical pesticides. The EPA also use less dangerous, more conventional pesticides.

**Push-pull strategy**

The word "push-pull" was used to describe an integrated pest management strategy in 1987 (IPM ). This strategy modifies the distribution and population of insects by implementing a range of behavior-modifying triggers. We mean to "push" insects from the desired crop in agriculture. Using external forces, such as pheromones, food additives, visual cues, biologically modified crops and others, to entice pests into traps where they can be killed is referred to as "pulling" (Cook et al., 2007). Numerous case studies from around the world have examined the effectiveness of the push-pull strategy. The push-pull farming method, which has proven to be most successful for subsistence farming, was invented in Africa. A successful experiment dealt with the prevention of Helicover pain crops in Australia. In order to control Sitonalineatus in bean fields, push-pull techniques were successfully used in Europe, the Middle East, and the United States (Cook et al., 2007). during push-pull process, there is less chemical or biological material usage, and insects are better protected from developing a tolerance to this type of control. There are some drawbacks to the push-pull strategy, such as its unreliability in the absence of sufficient understanding of the psychosocial and chemical ecology of cell interaction.

**Effectiveness**

Pesticide alternatives may be just as efficient as using chemicals, according to some research. Sweden, for instance, has cut its usage of pesticides in half without significantly reducing agricultural production (Miller, 2004). Farmers in Indonesia have used fewer pesticides on their rice fields, cutting back by 65 percent, and their crops have increased by 15 percent (Miller, 2004). It has been shown that applying composted yard trash to agricultural areas with a high carbon to nitrogen ratio is particularly efficient in decreasing the number of plant-parasitic nematodes and enhancing crop yields, with improvements in output varying from 10% to 212%. The impacts were long-lasting and usually did not surface until the study's third season. Northern Florida's corn fields were the subject of the investigation (MoSorley et al., 1996). Pesticide resistance, however, is rising. Only 7% of American farmers' crops were destroyed by pests in the 1940s. Despite the fact that additional pesticides are being applied, loss has climbed to 13 percent since the 1980s. Since 1945, there have been 500 to 1,000 resistances.

**Benefits of Pesticide Residues**

The primary benefits are the outcomes of the pesticides' activities or the predicted quick benefits of their usage. For instance, destroying caterpillars that are eating the crop primarily increases yields and enhances the quality of the cabbage. The three main impacts preserve recreational areas, save lives, and have other beneficial aspects as well. The advantages that flow from the core benefits but are less immediate or obvious are known as the secondary benefits.

**Protection against crop losses and declining yields**

Drawing parallels with control (weedy) plots, medium land rice even under puddle conditions during the crucial time required an effective and affordable weed management technique to prevent a drop in rice production owing to weeds that ranged from 28 to 48 percent (Behera and Singh, 1999). Weeds reduce the output of dry land crops by 37 to 79 percent, according to Behera and Singh (1999). Severe weed infestation eventually results in a 40% production loss, especially in the early phases of crop establishment. Herbicides helped the workers and the economy.

### Vector disease control

Eliminating the vectors is the most effective strategy to stop illnesses carried by them. When it comes to controlling insects that carry illnesses like malaria, which is thought to be responsible for 5000 fatalities every day, insecticides are usually the only practical solution (Ross, 2005). In India, malaria is a major public health concern and one of the leading causes of sickness and mortality in poor nations, according to a 2004 paper by Bhatia. Creating a disease management plan is essential for cattle as well.

### Improving quality of food

In first-world countries, it has been seen that eating a diet rich in fresh produce overcomes any possible risks from ingesting crops with extremely low levels of pesticide residue (Brown, 2004). According to emerging evidence, regularly eating fruits and vegetables reduces the risk of many cancers, high blood pressure, heart disease, diabetes, stroke, and other chronic illnesses (Dietary Guidelines, 2005). According to a review of the nutritional value of apples and blueberries in the US diet by Lewis et al. (2005), their high antioxidant concentrations act as a barrier against heart disease and cancer. Lewis largely attributed the doubling of wild blueberry production and subsequent increases in consumption to the use of herbicides that improved weed control.

### Transport, sport complex, building

In the transportation sector, pesticides—especially herbicides—are often used. Herbicides and pesticides are used to preserve the turf on sports grounds, cricket fields, and golf courses. Insecticides protect buildings and other wooden structures against termite and wood-boring insect damage.

## 3. HAZARDS OF PESTICIDE RESIDUES

### Health Effects

Pesticide exposure can have both immediate and long-term health effects on people (EPA, 2007). Human exposure to excessive pesticides can result to various harmful health consequences which includes mild eye and skin irritation to more severe ones including effects on the brain system, hormone mimics that can cause reproductive problems, and even cancer (EPA, 2006). According to a 2007 study, the majority of studies on non-Hodgkin lymphoma and leukemia "showed beneficial correlations with pesticide exposure," which led to the suggestion that cosmetic pesticide use be decreased (Bassil et al., 2007). Exposure to organophosphate pesticides is strongly linked to neurobehavioral abnormalities (Jurewicz et al., 2008; Weselak et al., 2007; Wigle et al., 2008; Mink et al., 2011). Additionally, there is no evidence of additional negative consequences of pesticide exposure, such as neurological problems, birth defects, and fetal death (Sanborn et al., 2007). Despite finding correlations between autism and exposure to certain pesticides in 2014, an epidemiological review warned that there was not enough evidence to establish a causal relationship (Kalkbrenner et al., 2014). Large volumes of purportedly harmless petroleum oil by-products are discharged into the environment as emulsifiers and pesticide dispersion agents. A 1976 study on young mice that had been pre-primed with such drugs revealed an increase in viral lethality with concomitant effects on the liver and central nervous system (Crocker et al., 1976)


**Figure 4.** A sign warning about potential pesticide exposure

**Effect on the Environment**

Pesticide use contributes to a variety of environmental problems. Spraying herbicides and insecticides onto surfaces causes them to land in places they weren't intended to, including non-target species, air, water, and soil (Miller, 2004). Pesticide drift is the term for when wind-borne pesticide particles are carried to nearby areas and may end up contaminating them. Use of some pesticides, which are persistent organic pollutants that can contaminate soil, flower nectar, and pollen, is one of the causes of water contamination (Tosi et al., 2018). Additionally, as pests might wander and harm surrounding crops that have not been treated with pesticides, the use of pesticides can have a detrimental impact on nearby agricultural enterprises. Pesticide use also reduces biodiversity, contributes to the decline of pollinators (Wells, 2007), deteriorates habitat (particularly for birds) (Palmer et al., 2008), and puts endangered and dangerous species in danger (Miller, 2004).

If pests develop resistance to the present pesticide, a new insecticide may be necessary (pesticide resistance). To overcome the resistance, a bigger dose of the pesticide might also be used, although doing so would make the problem of ambient pollution worse. According to the Stockholm Convention on Persistent Organic Pollutants, organochlorine pesticides made up 9 of the top 12 most dangerous and persistent organic chemicals, the majority of which are now largely no longer in use (Environmental Programme, 2005; Gilden et al., 2010). Because they dissolve in lipids and are not expelled, chlorinated hydrocarbon insecticides are frequently retained by organisms for almost indefinite periods of time. Through a process called as biological amplification, these chlorinated hydrocarbons (pesticides) grow more concentrated at each link in the food chain. Pesticide levels are much higher in fish-eating birds and mammals at the top of the ecological pyramid and higher in carnivorous fish among marine species (Castro et al., 2010). Through a process known as global distillation, pesticides are transported from warmer to colder regions of the world, notably to the poles and mountain summits.

Thousands of kilometers can be covered by the wind to carry pesticides to a place with lower temperatures, where they condense and are then returned to the ground in the form of rain or snow (Quinn, 2007).

**Groundwater contamination**

Groundwater contamination brought on by pesticides is a problem. According to the USGS, groundwater has been discovered to contain at least 143 different pesticides from every chemical class as well as 21 transformation products. More than 43 states have discovered groundwater (Waskom, 1994). In an Indian study, organochlorine pesticide levels in drinking water samples from wells and hand pumps close to the city of Bhopal were found to be 58 percent higher than EPA recommendations (Kole and Bagchi, 1995). Several years may pass before the pollution of ground water is removed or cleaned up after harmful chemicals have polluted it. Furthermore, cleanup may be very costly, challenging, or even impossible (Waskom 1994; O'Neil 1998; USEPA 2001).

**Non-target organisms**

Pesticides are a common cause of pollution in modern urban habitats, affecting non-target animals as well as the soil, air, and water. Once there, they might harm beneficial soil microbes and insects as well as non-target plants, fish, birds, and other animals. Fish fatalities have occurred in rivers near treated areas or buildings as a result of chlorpyrifos, a common urban stream pollutant (U.S. Geological Survey, 1999). (US EPA, 2000). Herbicides can harm fish as well. The EPA alleges that trifluralin, a substance included in the weed pesticide Snapshot, is "very to very highly toxic to both cold and warm water fish" (U.S.EPA, 1996). In several investigations, it was also shown to cause anomalies in fish's vertebrae (Koyama, 1996). Fish are very vulnerable to the two weed herbicides Ronstar and Roundup (Folmar et al., 1979; Shafiei and Costa, 1990). The extreme toxicity of one of Round up's inactive ingredients is most likely what makes the product so dangerous (Folmar et al., 1979)

**Pesticides Metabolism**

Pesticide biotransformation is the process of converting lipophilic foreign compounds into hydrophilic metabolites through enzymatic catalysis (Scarpato etal.,1996). The two groups of metabolic enzymes are phase I and phase II enzymes (Oesch et al., 2000). However, additional enzymes that catalyze the oxidation of certain functional groups include flavin monooxygenases, peroxidases, amineoxidases, dehydrogenases, and xanthine oxidases. The cytochrome P450 enzyme family plays a major role in phase I reactions. Other hydrolytic reaction types, such as carboxyl esterases and epoxide hydrolases, are catalyzed by enzymes in addition to oxidative processes, as shown in Figure 5.

Phase I products are more readily excreted when a substrate such glucuronic acid, sulfuric acid, acetic acid, or an amino acid interacts with an existing, recently introduced, or exposed functional group to form a highly polar conjugate. Phase I items often take longer to eliminate (Rose et al., 2004). The three kinds of proteins involved in the removal of pesticides from the body include phase I (oxidative) metabolizing enzymes, phase II (conjugative) metabolizing enzymes, or phase III transporters engaged in efflux processes. The main enzymes of phase I metabolism are the heme-thiolate proteins of the cytochrome P450 super family (CYPs). UDP-glucuronosyl transferases (UGT), Sulfotransferases (SULT), Glutathione-S-transferases (GST), and N-acetyl transferases all create functional groups that might later serve as a conjugation site (NAT).

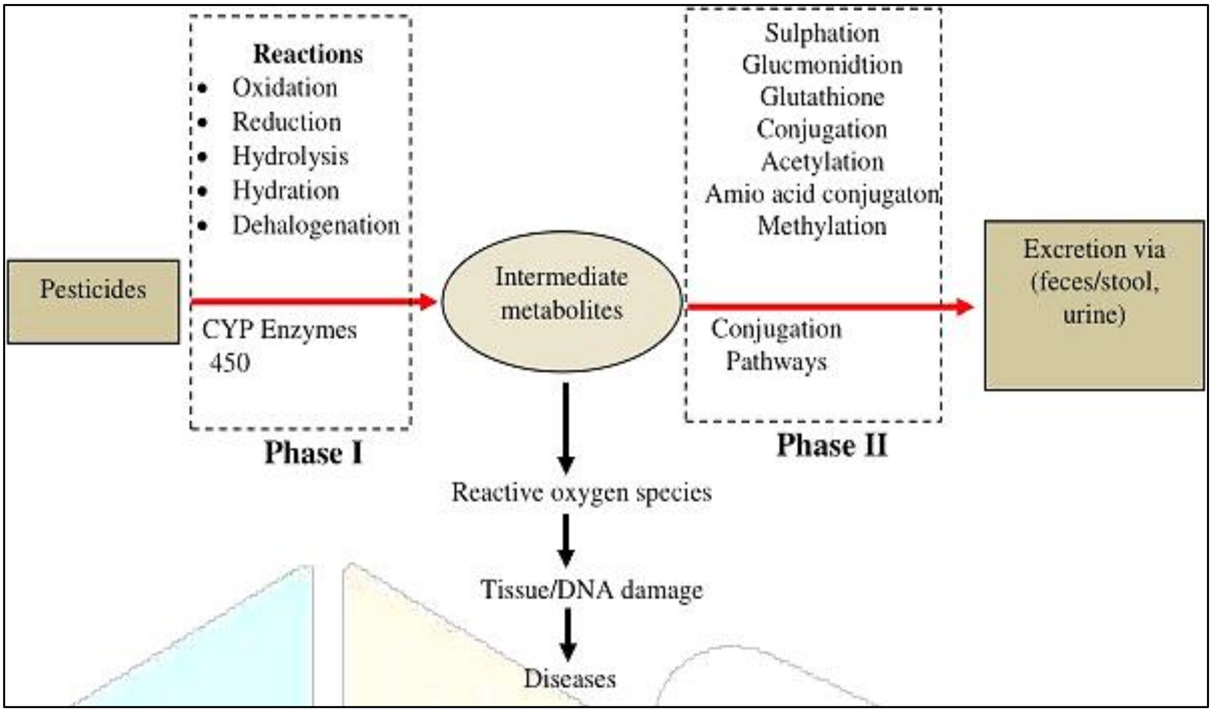



**Figure 5.** Types of reaction involved in Pesticides Metabolism (Parkinson et al., 2001)

**Table 2.** Specific Pesticides Metabolized by CYP Enzyme

| Pesticides | CYP involved | Pathway | Reference |
|---|---|---|---|
| Altrazine | CYP1A1, CYP2C9, CYP2C19etc….. | N-Deethylation and N-Deisoptopylation | Joo et al., 2010; Lang et al., 1997 |
| Carbaryl | CYP1A2, CYP2D6, CYP3A4etc….. | Aromatic hydroxylation and Methyloxidation | Tang et al., 2002 |
| Carbofuran | CYP3A4, CYP1A2, CYP2C19etc….. | Ring oxidation | Usmani et al., 2004 |
| Carbosulfan | CYP2E1, CYP3A7, CYP2C8etc….. | N-S Cleavage and Sulfoxidation | Abass et al., 2010 |

| | | | |
|---|---|---|---|
| Diazion | CYP3A5, CYP2D6,<br><br>CYP1A2etc….. | Desulfuration | Buratti et al., 2002 |
| Diuron | CYP1A1, CYP2C9,<br><br>CYP1A2etc…. | N-Demethylation | Xang et al., 2002 |

Certain enzymatic reactions are necessary for a lipophilic chemical to biotransform into a water-soluble product that can be removed in urine. Phase III transporters, such as P-glycoprotein (Pgp), multi-drug resistance related proteins (M RPs), and organic anion transporting polypeptide 2 (OATP2), are expressed in a variety of organs, such as the liver, gut, kidney, and brain. For pesticides to be absorbed, distributed, and expelled, these transporters are necessary. It has been shown that pretreatment with different inducers or inhibitors affects phase III transporter expression, which eventually results in altered pesticide excretion, in addition to phase I and phase II enzyme induction/inhibition. The cellular stress response, which in turn promotes gene expression, may be triggered by phase I, phase II, and phase III inducer exposure. This would enhance the clearance and removal of pesticides

**Preventive Measures to Reduce Pesticide Residues in Crops**

Different pesticides are used on various types of crops in various nations to prevent pests, insects, and weeds. As international commerce has increased, more foods that have been pesticide-treated are being imported into other countries. Because of this global trade, the public is worried about the rising levels of pesticide residues in diverse regions of the world. Several steps may be taken to lessen insect and disease problems as well as the quantity of pesticide residues in grains, vegetables, and fruits (Gale et al., 2009).

**Organic farming**

One strategy to decrease the effects of pesticide residue in food is to consume organic foods rather than non-organic ones. According to common meta-analyses, non-organic crops contained detectable pesticide residues four times more frequently than organic ones (Baranski et al., 2014). Consuming organic foods may help reduce your exposure to pesticide residues in food, according to the evidence (Smith-Spangler et al., 2014). Organic crops typically contain greater antioxidant concentrations and fewer instances of pesticide residues than non-organic foods in all regions and production seasons. By inhibiting oxidative activity, eating foods strong in antioxidants is recommended to minimize the effects of chronic illness.

**Washing food products**

The second method to reduce pesticide residue in food has been recommended is washing. Cleaning may lessen the amount of pesticide residue on food products. For both domestic and commercial use, it's crucial to wash with water and various chemical treatments to eliminate pesticide residues. How well washing procedures remove pesticides depends on a number of factors, including the washing solution, the pesticide's chemical properties, the surface area, the kind of food, the duration of the pesticide's interaction with the food, and the formulation and application technique of the pesticide.

**Processing food products**

Most foods undergo processing steps before consumption, such as washing, peeling, canning, and cooking, which are essential in minimizing residues left on crops at harvest (Hollan et al., 1994). The amount of pesticide residue in fruits and vegetables can vary depending on the processing methods used, such as peeling, boiling, frying, fermentation, and grinding (Claeys et al., 2011). Cooking also reduces food residues; for instance, boiling can reduce organochlorine residues by 20 to 25 percent and organophosphate residues by 35 to 60 percent (Hollan et al., 1994). By being husked and immersed, fruit and vegetables are allegedly able to reduce pesticide residues, particularly organophosphates (Neme et al., 2016).

**Rational use of pesticides**

The rational use of pesticides includes the appropriate selection of pesticides, dose rates, dilutions, timing, frequency of application, treatment intervals, mode of administration, precautions, and restrictions. By using pesticides wisely, pesticide residues in food items may be reduced. Many times, especially when cultural or biological methods are effective, a pesticide may not even be required (Mukunya et al., 1988).

**Use of natural pesticides and biopesticides**

Bio-pesticides don't leave behind any hazardous residues and are harmless for the environment. The term "bio-pesticides" refers to a broad class of microbial pesticides that provide protection against insect damage via the use of biochemicals derived from microbes and other natural sources. To prevent the accumulation of pesticide residues in grains, vegetables, and fruits, certain insect repellents can also be employed (Gupta et al., 2010). Natural insecticides are also very efficient in preventing the accumulation of pesticide residues in food items, such as those made from chemicals and neem tree extracts (Schmutterer et al., 1990).

**Implementation and amendment of pesticide-related laws**

The Insecticides Act of 1968 mandates that the Ministry of Agriculture in India be in charge of overseeing the manufacturing, distribution, sale, import, and export of pesticides as well as their usage. The Pesticide Management Bill of 2008, which seeks to repeal the Insecticides Act of 1968, was presented to Parliament in 2008 but has not yet been approved. Laws controlling pesticides must be properly applied and updated in order to reduce the prevalence of food grains bearing pesticide residues (Sharma, 2017).

**Regulations of Pesticides for Safe Use**

Pesticides must be marketed and used with government authorisation in several countries (Wilson, 1996). The use of very toxic pesticides, such as those that are endocrine disrupting, carcinogenic, mutagenic, or toxic to reproduction, persistent, bioaccumulative, and toxic (PBT), or very persistent and very bioaccumulative (vPvB), is prohibited in all of the EU's member states (US Parliament, 2009).

Pesticides and the products they were used on are traded globally despite the fact that various countries have different laws controlling them. Delegates at a United Nations Food and Agriculture Organization conference adopted an international code of conduct on the distribution and use of pesticides in 1985 to resolve regulatory differences between nations. For several countries, this code set voluntary pesticide regulating norms (Wilson, 1996). The Code was updated in 1998 and 2002.

According to the FAO, the code has raised awareness of the dangers associated with pesticides and decreased the number of countries that do not have legislation regulating their use (FAO, 2013). Two further attempts to improve global pesticide control are the United Nations Codex Alimentarius Commission and the United Nations London Guidelines for the Exchange of Information on Chemicals in International Trade. In contrast to the latter, the former aims to set global norms for the maximum pesticide residue levels among participating governments.

The former aims to develop processes to ensure that prior informed consent exists between nations acquiring and selling pesticides (Raynolds, 1997). By educating the public about pesticide safety and regulating pesticide applicators, the public is intended to be safeguarded against abuse of pesticides, although misuse still occurs.

The risks of pesticide usage to society and the environment can be reduced by using fewer pesticides and less hazardous chemicals (Helfrich et al., 1996). A rising number of countries have successfully implemented integrated pest management, which makes use of a range of pest-control methods, including Indonesia, China, Bangladesh, the United States, Australia, and Mexico (Miller, 2004).

IPM seeks to assess the broader effects of an activity on an ecosystem in order to avoid disrupting natural equilibrium (Daly et al., 1998). New insecticides, including biological and botanical compounds, are being developed, along with possible replacements that should be less hazardous to the environment and public health. Additionally, it is advised that applicators use less chemical pesticides and consider employing alternative controls. It is possible to create insecticides that are environmentally benign and target a particular pest's lifecycle (NWO, 2001). For instance, potato cyst nematodes emerge from their protective cysts and feed on the crop, inflicting harm, in response to a chemical emitted by potatoes (NWO, 2001). Similar chemicals can be applied on fields prior to planting potatoes to encourage nematodes to emerge early and starve in the absence of potatoes (NWO, 2001).

## 4. CONCLUSION

Pesticides have long been employed in agricultural operations, therefore there are many reasons to be worried about the effects of pesticide residues in food crops. A pesticide's efficacy is influenced by both the type and dosage utilized. Although pesticides can boost agricultural output, due to inadequate management, their residues are a significant contributor to a wide range of environmental degradation (air, land, and water). The cause of this contamination is pesticides.

Pesticide residues may enter a person's body when they breathe in polluted air, drink contaminated water, or eat improperly cleansed food crops. Numerous diseases, including as asthma, anxiety, sadness, leukemia, and attention deficit hyperactivity disorder (ADHD), can be brought on by either form of pesticide residue. Certain pesticide residues can cause cancer, whereas others do not (ADHD). Before eating or processing food crops, we should carefully wash them to prevent them. By employing biodegradable pesticides, we must also ensure that enough organic farming is being done.

**References**


[1] Aldridge, J.E., Meyer, A., Seidler, F.J., and Slotkin, T. (2005). Alteration in central nervous system serotonergic and dopaminergic synaptive activity in adulthood after prenatal or neonatal chlorpyrifos exposure. *Environ Health Perspective* 113: 1027-1031

[2] Andreu,V., and Picó, Y. (2012). Determination of currently used pesticides in biota. *Analytical and Bioanalytical Chemistry* 404(9): 2659-2681

[3] Assunção, N.A., Bechara, E.J.H., Simionato, A.V.C., Tavares, M.F.G., and Carrilho, E. (2008). Capillary electrophoresis coupled to mass spectrometry (CE-MS): twenty years of development. *Química Nova,* 31: 2124-2133

[4] Baldi, I., Lebailly, P., Jean, S., Rougetet, L., Dulaurent, S., and Marquet, P. (2006). Pesticide contamination of workers in vineyards in France. *Journal of Exposure Science and Environmental Epidemiology,* 16: 115-124

[5] Baranski, M., Srednicka-Tober, D., and Volakakis, N. (2014). Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues inorganically grown crops: a systematic literature review and meta-analyses. *Britain Journal of Nutrition,* 112(5): 794-811

[6] Bassil, K.L., Vakil, C., Sanborn, M., Cole, D.C., Kaur, J.S., and Kerr, K.J. (2007). Cancer health effects of pesticides: systematic review. *Canadian Family Physician,* 53(10): 1704–1711

[7] Behera, B., and Singh, S.G. (1999). Studies on Weed Management in Monsoon Season Crop of Tomato. *Indian Journal of Weed Science*, 31(1–2): 67

[8] Berthet, A., Hopf, N.B., Miles, A., Spring, P., Charrière, N., Garrigou, A., Baldi, I., and Vernez, D. (2014). Human skin in vitro permeation of bentazon and isoproturon formulations with or without protective clothing suit. *Archieves of Toxicology,* 88: 77-88

[9] Chan, T.Y.K., and Critchley, J.A.J.H. (1998). Insecticides poisoning with Organophosphates and carbamates. *Hong Kong Practioner,* 20: 604-613

[10] Claeys, W.L., Schmit, J., and Bragard, C. (2011). Exposure of several Belgian consumer groups to pesticide residues through fresh fruit and vegetable consumption. *Food Control*, 22(3-4): 508-516

[11] Cook, S.M., Khan, Z.R., and Pickett, J.A. (2007). The use of push-pull strategies inintegrated pest management. *Annual Review of Entomology,* 52(1): 375–400

[12] Colović, M.B., Krstić, D.Z., Lazarević-Pašti, T.D., Bondžić, A.M., and Vasić, V.M. (2013). Acetylcholinesterase inhibitors: pharmacology and toxicology. *Current Neuropharmacology*, 11(3): 315–335

[13] Crocker, J.F., Ozere, R.L., andSafe, S.H. (1976). Lethal interaction of ubiquitous insecticide carriers with virus. *Science,* 192(4246): 1351–1353

[14] Daly, H.V., Doyen, J.T., and Purcell, A.H. (1998). Introduction to insect biology and diversity (2nded.). Oxford: Oxford University Press, 279–300.

[15] Dietary guidelines for Americans. (2005). U.S. Department of Health and Human Services U.S. Department of Agriculture.

[16] Di Stefano, V., Avellone, G., Bongiorno, D., Cunsolo, V., Muccilli, V., Sforza, S., Dossena, A., Drahos, L., and Vékey, K. (2012). Applications of liquid chromatography-mass spectrometry for food analysis. *Journal of Chromatography A*, 1259: 74-85

[17] FAO (1986). Food and agricultural organization of the United Nation. International code of conduct on the distribution and use of pesticides, Rome.

[18] Folmar, L.C., Sanders, H.O. and Julin, A.M. (1979). Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. *Archive of Environment Contamination Toxicology,* 8: 269–278

[19] Gilden, R.C., Huffling, K., and Sattler, B. (2010). Pesticides and health risks. *Journal of Obstetric, Gynecologic, and Neonatal Nursing,* 39(1): 103–110

[20] Gill, R.J., Ramos- Rodriguez, O., and Raine, N.E. (2012). Combined pesticide exposure severely affects individual-and colony-level traits in bees. *Nature,* 491(7422): 105–108

[21] Goldman, L.R. (2007). Managing pesticide chronic health risks: U.S. policies. *Journal of Agromedicine*,12(1): 67–75

[22] Gunnell, D., Eddleston, M., Phillips, M.R., and Konradsen, F. (2007). The global distribution of fatal pesticide self-poisoning: systematic review. *BMC Public Health,* 7(1): 357

[23] Gupta, S., and Dikshit, A.K. (2010). Biopesticides: Aneco- friendly approach for pest control. *Journal of Biopesticides,* 3(1): 186-188

[24] Hashmi, I., and Dilshad, K.A. (2011). Adverse Health Effects of Pesticides Exposure in Agricultural and Industrial Workers of Developing Country. *Pesticides - The Impacts of Pesticides Exposure,* 155-178. DOI: 10.5772/13835

[25] Helfrich, L.A., and W eigmann, D.L. (1996). Pesticides and aquatic animals: A guide to reducing impacts on aquatic systems. Virginia Cooperative Extension, Archived from the original on March 5, 2009. Retrieved Oct 14, 2007.

[26] Hodgson, E., and Goldstein, J.A. (2001). Metabolism of toxicants: phase I reactions and pharmacogenetics, In: Introduction to Biochemical Toxicology, Hodgson, E. & Smart, R.C., (Ed.), Wiely, 67-113, New York.

[27] Holland, P.T., Hamilton, D., and Ohlin, B. (1994). Pesticides report 31: effects of storage and processing on pesticide residues in plant products (technical report). *Pure and Applied Chemistry* 66(2): 335-346

[28] Icenogle, L.M., Christopher, N.C., Blackwelder, W.P., Caldwell, D.P., Qiao, D., and Seidler, F.J. (2004). Behavioral alterations in adolescent and adult rats caused by a brief subtoxic exposure to chlorpyrifos during neurulation. *Neurotoxicology and Teratology,* 26: 95–101.

[29] Jurewicz, J., and Hanke, W. (2008). Prenatal and childhood exposure to pesticides and neurobehavioral development: review of epidemiological studies. *International Journal of Occupational Medicine and Environmental Health*, 21(2): 121–132

[30] Kalkbrenner, A.E., Schmidt, R.J., and Penlesky, A.C. (2014). Environmental chemical exposures and autism spectrum disorders: a review of the epidemiological evidence. *Current Problems in Pediatric and Adolescent Health Care*, 44(10): 277–318

[31] Kole, R.K., Banerjee, H., Bhattacharyya, A, Chowdhury ,A. and Aditya Chaudhury, N. (1999). Phototransformation of some pesticides. *Journal of Indian Chemistry and Sociology*, 76: 595–600

[32] Koyama, J. (1996). Vertebral deformity susceptibilities of marine fishes exposed to herbicide. *Bull Environment Contamination Toxicology*, 56: 655–662

[33] Lamberth, C., Jeanmart, S., Luksch, T., and Plant, A. (2013). Current challenges and trends in the discovery of agrochemicals. *Science*, 341(6147): 742–746

[34] Lewis, N.M. and Jamie, R. (2005). Blueberries in the American Diet. *Nutrition Today*, 40(2): 92

[35] Macfarlane, E., Carey, R., Keegel, T., El-Zaemay, S., and Fritschi, L. (2013). Dermal exposure associated with occupational end use of pesticides and the role of protective measures. *Safety and Health at Work*, 4: 136–141

[36] Martins, J.G., Amaya, C.A., Waliszewski, S.M., Colín, C.A, and Fabila, M.M. (2013). Extraction and clean-up methods for organochlorine pesticides determination in milk. *Chemosphere* 92(3): 233-246.

[37] Mason, H.J. (2000). The recovery of plasma cholinesterase and erythrocyte acetylcholinesterase activity in workers after over exposure to dichlorovos. *Occupational Medicine*, 50: 343-347

[38] McSorley, R., and Gallaher, R.N. (1996). Effect of yard waste compost on nematode densities and maize yield. *Journal of Nematology*, 28(4): 655–660

[39] Miller, G.T. (2004). Biodiversity. Sustaining the Earth (6thed.). Pacific Grove, CA: Thompson Learning, 211–216

[40] Mink, P.J., Mandel, J.S., Lundin, J.I., and Sceurman, B.K. (2011). Epidemiologic studies of glyphosate and non-cancer health outcomes: a review. *Regulatory Toxicology and Pharmacology*, 61(2): 172–184

[41] Mukunya, D.M., and Muinamia, C. (1988). Rational use of pesticides in horticulture with special emphasis on Kenya. *Acta Horticulture*, 218: 261-266

[42] Neme, K., and Satheesh, N. (2016). Review on pesticide residue in plant food products: health impacts and mechanisms to reduce the residue levels in food. *Archive of Applied Science and Resources*, 8(3): 55-60

[43] Oesch, F., Herrero, M.E., Hengstler, J.G., Lohmann, M., and Arand, M. (2000). Metabolic Detoxification: Implications for Thresholds. *Toxicologic Pathology*, 28(3): 382-387

[44] O'Neil, W. and Raucher, R. (1998). Groundwater public policy leaflet series #4: The costs of groundwater contamination. Wayzata, MN: Groundwater Policy Education Project. http://www.dnr.state.wi.us/org/water/dwg/gw/costofgw.htm (Aug.)

[45] Pal, G.K., and Kumar, B. (2013). Antifungal activity of some common weed extracts against wilt causing fungi, Fusarium oxysporum. *Current Discovery*, 2(1): 62–67

[46] Pimentel, D. (2005). Environmental and economic costs of the application of pesticides primarily in the United States. *Environ Develop Sustainability,* 7: 229-252

[47] Pimental, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., and Nelson, J. (1992). Environmental and economic costs of pesticide use. *Bioscience*, 42: 750-760

[48] Poole, C.F. (2013). Derivatization reactions for use with the electron-capture detector. *Journal of Chromatography A,* 1296: 15-24

[49] Randall, C. (2014). Pest Management. National Pesticide Applicator Certification Core Manual (2nded.), Washington: National Association of State Departments of Agriculture Research Foundation.

[50] Rao, G.V., Rupela, O.P., Rao, V.R., and Reddy, Y.V. (2007). Role of biopesticides in crop protection: present status and future prospects. *Indian Journal of Plant Protection*, 35(1): 1–9

[51] Reynolds, J.D (1997). International Pesticide Trade: Is There any Hope for the Effective Regulation of Controlled Substances. *Journal of Land Use & Environmental Law*, 13(1): 69–105

[52] Ross, P.S., de Swart, R.L., Reijnders, P.J.H., Loveren, H.V., Vos,J.G. ,and Osterhaus, A.D.M.E.(1995). Contaminant-related suppression of delayed-type hypersensitivity and antibody responses in harbor seals fed herring from the Baltic Sea. *Environ Health Perspective*, 103: 162–167

[53] Sallam, A.A., Ibrahim, M.S., and Nasr, I.N. (2006). Monitoring of organochlorine and organophosphorous residues in sediments of river Nile, Egypt. *Journal of Agriculture Mansoura University,* 31: 2451-2469

[54] Sanborn, M., Kerr, K.J., Sanin, L.H., Cole, D.C., Bassil, K.L., and Vakil, C. (2007). Non-cancer health effects of pesticides: systematic review and implications for family doctors. *Canadian Family Physician*, 53(10): 1712–1720

[55] Santaladchaiyakit, Y., Srijaranai, S., and Burakham, R. (2012). Methodological aspects of sample preparation for the determination of carbamate residues: a review. *Journal of Separation Science*, 35(18): 2373-2389

[56] Scarpato, L., Migliore, G., Angotzi, A., Fedi, L., and Miligi, N. (1996). Cytogenetic monitoring of a group of Italian floriculturists: no evidence of DNA damage related to pesticide exposure. *Mutation Research* 367(2): 73-82

[57] Schmutterer, H. (1990). Properties and potential of natural pesticides from the neem tree, Azadirachtaindica. *Annual Review on Entomology,* 35: 271-297

[58] Slotkin, T. (1999). Developmental cholinotoxicants: nicotine and chlorpyrifos. *Environ Health Perspective,* 107: 71–80

[59] Smith-Spangler, C., Brandeau, M.L., and Hunter, G.E. (2012). Are organic foods safer or healthier than conventional alternatives: a systematic review. *Annual International Medicine,* 157(5): 348-366

[60] Soares, W., Almeida, R.M.V.R., and Moro, S. (2003). Rural work and risk factors associated with pesticide use in Minas Gerais, Brazil. *Cadian Saúde Pública,* 19: 1117-1127

[61] Soderlund, D. (2010). Toxicology and Mode of Action of Pyrethroid Insecticides. Hayes Handbook of Pesticide Toxicology (3ed.) Academic Press, 1665–1686.

[62] Tosi, S., Costa, C., Vesco, U., Quaglia, G., and Guido, G. (2018). A survey of honey bee-collected pollen reveals widespread contamination by agricultural pesticides. *Science of the Total Environment,* 615: 208–218

[63] Travisi, M., and Nijkamp, P. (1998). Valuing environmental and health risk in agriculture: a choice experiment approach to pesticides in Italy. *Ecology Economic,* 67: 598-607

[64] U.S. EPA. Office of Prevention, Pesticides, and Toxic Substances. (1996). Reregistration eligibility decision (RED): trifluralin. Washington, D.C., April.

[65] U.S. Geological Survey. (1998). National Water- Quality Assessment. Pesticide National Synthesis Project. Pesticides in surface and groundwater of the United States; Summary of results of the National Water Quality Assessment Program. http://water.wr.usgs.gov/pnsp/allsum/fig02.gif

[66] Wen, Y., Fu, Z., Xu, J., Tang, S., Wang, Q., Li, H., Xie, G., Zhu, Y., Gu, Y., and Tan, F. (2014). Determination of 2, 4-dichlorophenoxyacetic acid in air of workplace by high-performance liquid chromatography. *Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi.* 32(6): 458-459

[67] Weselak, M., Arbuckle, T.E., and Foster, W. (2007). Pesticide exposures and developmental outcomes: the epidemiological evidence. *Journal of Toxicology and Environmental Health*, 10(1–2): 41–80

[68] WHO (2006). WHO gives indoor use of DDT a clean bill of health for controlling malaria. Retrieved Sep 13, 2007.

[69] WHO (2006). Indoor residual spraying: Use of indoor residual spraying for scaling up global malaria control and elimination. Global Malaria Programme.

[70] Wigle, D.T., Arbuckle, T.E., Turner, M.C., Bérubé, A., Yang, Q., Liu, S., and Krewski, D. (2008). Epidemiologic evidence of relationships between reproductive and child health outcomes and environmental chemical contaminants. *Journal of Toxicology and Environmental Health,* 11(5–6): 373–517

[71] Yamamoto, I. (1999). Nicotine to Nicotinoids: 1962 to 1997. In Yamamoto I, CasidaJ (eds.). Nicotinoid Insecticides and the Nicotinic Acetylcholine Receptor. Tokyo: Springer-Verlag, 3–27.

[72] Zamek-Gliszczynski, M.J., Hoffmaster,K.A., Nezasa,K., Tallman,M.N., and Brouwer, K.L.R. (2006). Integration of hepatic drug transporters and phase II metabolizing enzymes: mechanisms of hepatic excretion of sulfate, glucuronide, and glutathione metabolites. *European Journal of Pharmaceutical Science,* 27: 447-486