IJSRIS journal

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH AND INNOVATIVE STUDIES

ISSN: 2820-7157
www.ijsrisjournal.com

August 2022 Volume 1 Number 2 Pages 9-25

Pesticide Residues in Vegetables: a Public Health Concern

Bando Christopher David[1], Imo Chinedu[2], Ogu Odiba Emmanuel[3], Ifraimu Daniel[4], Jesse Shingu Polly[5], Oche Gabriel Sunday[6], David Haruna Ephraim[7]

[1]National Biotechnology Development Agency, Abuja, Nigeria, bandomidase@gmail.com
[2] Department of Biochemistry,Federal University Wukari, Nigeria, chinedu04@yahoo.com
[3]National Biotechnology Development Agency, Abuja, Nigeria, talk2odibs@gmail.com
[4]National Biotechnology Development Agency, Abuja, Nigeria, danielifraimu@yahoo.com
[5]National Biotechnology Development Agency, Abuja, Nigeria, polly_jesse@yahoo.ca
[6]National Biotechnology Development Agency, Abuja, Nigeria, ochesundaygabriel80@gmail.com
[7]Department of Biochemistry,Federal University Wukari, Nigeria, mobankz4real@gmail.com

ABSTRACT

It is impossible to overstate the economic importance of pesticide residues in vegetables and ecosystem. Relatively good amount of pesticides are naturally persistent (organochlorines, DDT) which is deposited and biomagnify in higher-trophic-level biological system. It is critical to properly examine the risks of eating pesticide-treated vegetables. As agriculture becomes more intense, more hazardous organic and inorganic compounds are released into the environment. Pesticides are among the most harmful compounds polluting the environment, due to its popular usage, toxicity specificity, able to bioaccumulate in organisms and are very stable. They are especially harmful in vegetables, which expose people to them. Pesticide residues in vegetables must therefore be closely monitored. These pesticides pose great threat to the environment and consequently to global health as a result of their general usage. Pesticides are classification as: Based on their toxicity/hazardous effects; use/purpose; chemical makeup; mode of action; function (how or when), and source of origin. Pesticides mode of actions in plants and animals basically is inhibition of some biochemical pathways (photosynthesis, growth hormones, enzymes activities, respiration etc.).

Keywords: Bioaccumulation, Biomagnification, Pesticide residues, Public health, Vegetable.

INTRODUCTION

Agriculture, which in most parts of the world is the popular basic kind of livelihood activity, is experiencing major setbacks. The actions of other living components of the environment, including parasites, diseases, and fungus, and weeds, can undercut the efforts of farmers. These are not only competitors with farmers in terms of available resources, but they could serve as disease agents for agricultural products. The pests exert adverse effect on agricultural goods by diminishing production to the point that farming becomes unprofitable for the farmers. Farmers are required to look into techniques to control undesirable organisms in order to reduce wastage. Pesticides, which are purchased and applied to cultivation grounds, agricultural products in farms and in store to prevent agricultural produce from the ravages of these pests, are one method of pest management [1]. As a result, there is a need to control this threat, which has resulted to the evolvement of "pesticides." Pest infestations in these crops are frequently met with massive pesticide treatments, endangering environmental quality and posing health concerns to humans and animals. Pesticides applied in vegetable farming include parathion and furadan/carbofuran which are WHO toxicity Class 1a and Class 1b substances respectively [2].

Because of the cost of the chemicals (most of which are patented), as well as the high rate of manpower and the type of unfriendly organisms of each location, pesticide use has not been uniform over the world [2].

Pesticides are an example of agrochemicals which are chemicals that have been applied to an agro-ecosystem. Some pest killers possess high level of solubility, and they are usually carried along with the water flow. Physical and chemical features of pesticides are; volatility, highly soluble, high absorption ability and the propensity for degradation [3;4]. Aside from acute poisoning, pesticides have a number of negative consequences on human health. Many studies have found links between agricultural chemical exposure and various health outcomes, such as cancer and degenerative disorders [5]. Researchers have reported effects on the immune, reproductive systems, hematological, endocrine, and nervous, and these substances has direct linked to human DNA damage [6;7;8;9]. Low-level pesticide exposure is known to cause a number of alterations of biochemical processes, which part of it could be to blame for the negative consequences on living processes seen in life science research [10;11;12].

Contamination of the environmental is a worldwide problem; the hazards and consequences for biological health are major concern. Recent state of environmental pollution is an anthropogenic disaster, yet there is need to considered benefit-risk ratio in making a complaint about pollution [13]. Pesticides have been applied in agriculture using a variety of strategies, ranging from spraying by people on walking, on truck and engaging of airplane-based spraying. Some or all of these strategies have been utilized at various times and in various areas. During pesticide applications, there has been occurrence of intoxication of users, as reported by several researches on toxicity and the impact of non-biological substances on human and global health. Non deliberate Poisonings has killed an estimated number of individuals of about 355,000 globally yearly, according to reports, and these poisonings are strongly linked to excessive exposure and inappropriate usage of harmful chemicals [14;15;16]. Microorganisms in soil, other living organisms such as; earthworms, snails, frogs, birds, and other species which are beneficial to the environment can all be killed by pesticides. Soil microbes are important for the preservation of soil values, mineralization and biochemical transformation of organic materials, and the availability of nutrients to plants. Pesticide use (particularly in long term) can result in irreversible population alterations. The suppression of species that provide critical processes can have a noticeable effect on the overall beneficial features of the ecosystem [17;18]. However, because of the deleterious effects on the ecosystem, reliance on pest killers is difficult to maintain. Pesticides are mostly hazardous to both man and the environment due to their high toxicity [19].

Regardless that pesticide industrial production are guided by stringent rules and regulations processes in order to be highly effective and have little or no harmful effect to human health, application of these pesticides in large quantities results in bioaccumulation of their residual components, which are the active constituent's deposit [20;21]. The residual pest killers dispersion in the environment and massive destruction of biotic species other than human, were also reported [22;23;24]. Based on the climatic condition that favoured cultivation of vegetables, they are now grown all over the world [25]. Pesticide residues found most frequently in vegetable samples are those that result from the pesticides applied to the vegetables to intentionally by the farmers in other combat unwanted organisms and diseases [26]. During this application of pesticides to exterminate pathogenic organisms or pests, just about 15 percent of the applied quantity reaches the target, leaving about 85 percent ending up in the environs [27].

Pesticides and pesticides residues

The chemical constituents of pesticides are mostly those that are widely adopted in modern age agricultural practices to protect plants from various pests, diseases and the causative agents [28;29]. They have been reported to largely increase agricultural yield, leading to an increase in their use over time [30]. They are used on the farm as well as in storage at homes and warehouses. They could be used for curative purposes, by removing or reducing pest populations using broad-spectrum pesticides, or in a preventative mode, where pesticides are applied prior to the pest's predicted infestation or attack. Pesticides could also be administered on a regular basis as a preventative measure to keep insect populations from growing. Biocides are pesticides that are employed outside of agriculture [18].

The residues pesticide are deposits of the active ingredient of the pesticide, its metabolites in the environment or in agricultural produce after it has been applied, spilled, or dumped [31]. Pesticide residues have drawn the attentions of users since they are found to have potentially negative impacts on creatures that are not pests related and illnesses [32]. Pesticide residues include residues from sources that are not known (e.g., environmental), as well as residues from documented pesticide usage. Every human being is concerned about the existence of residues in food, drink, and fodder. Pesticide residues are mostly caused by overuse and indiscriminate agricultural spraying. According to studies conducted by several institutes across the country, pesticide residues are found in 50-70 percent of vegetables [33;34].

Types of pesticides

Pesticides are divided into two categories/types.

A. Biopesticides, also known as non-synthetic or organic pesticides, are pesticides that exist naturally (as products of biological organisms) in plants or animals, such as Trichoderma, phytopthora, and canola oil.

B. Chemical pesticides, often known as "Synthetic" or "Inorganic" pesticides, which include organochlorine, carbamate, and organophosphate, among others.

Classification of pesticides

Pesticides are compounds or combination of compounds that differ from one another in terms of physical, chemical, and identical properties. As a result, these characteristics are used to classify them. Hence, they are also divided into various classes owing to their uses [35].

Botanical classification of pesticides

Botanical pesticides (botanicals) are bio-pesticide that are mostly used in agricultural pest control as a better replacement to conventional pesticides. The specific characteristics of botanicals, such as; non-persistence in nature and in-ability to bio-accumulate in the environment, pose no harm to insects that are of useful to the ecosystem, and less harmful to man [36], give rise to so much research interest into botanical pesticides are secondary metabolites derived from numerous plant sources. Generally, botanicals are friendly to the ecosystem than the synthetic pesticides [37].

Majorly and widely used botanicals in the agricultural pest control are;

(i). Neem Based Pesticides

Azadirachta indica (Neem), used to produce neem-based goods is from Meliaceae family [38]. Some active substances in neem are; desacetyl nimbin, salannin, desacetyl salannin, nimbin and nimbidin. An effective active component of the *Azadirachta indica* is azadirachtin, a tetranortriterpenoid limonoid [39]. In comparison to other sections of the neem tree, the seeds have a higher concentration of azadirachtin (0.2–0.6%) [40;41]. The Azadirachtin have a large range of insect-related activities, with ability to control or regulate insect growth and serve as repellents [42].

(ii) Pyrethrum

Pyrethrum made of six active ngredients is found various parts of plants but mostly in larger concentrations in the flowers [36;41;43;44]. Pyrethrins, cinerins, and jasmolins are found in a 10: 3: 1 ratio in a normal pyrethrum extracts. In terms of concentrations, the active component mostly in abundant is pyrethrins, then cinerins and jasmolins [39].

(iii) Eucalyptus Essential Oil

Phytochemicals found in eucalyptus oil are; Ketones, oxides, ethers, monoterpenes, alcohols, sesquiterpenes, aromatic phenols, and aldehydes. Its chemical components' constituents and proportions differ depending on the species. Eucalyptol, limonene, citronellal, citronellol, citronellyl acetate, eucamalol and linalool, are examples of pesticides found in eucalyptus oil [45;46;47]. The most important characteristic chemical among the many constituents of essential oil that have higher efficacy on pest control is 1, 8 –cineole [47]. The various chemical substances combine synergistically to produce the overall pesticide activity [33]. Eucalyptus leaf extracts, in addition to the essential oil, have insecticidal efficacy against a variety of pests. The Eucalyptus globulus Labill essential oil, which contains eucalyptol,–pinene, and–cymene, was found to be efficient against target pests by Koul *et al*. (2008) [40]. The *Eucalyptus globulus L*. leaf powder was discovered to have antibacterial properties. Prostephanus trunatus was found to be insecticidal [48]. In a research by Singh *et al*., (2012) [49] discovered that leaf extracts from three plants, neem plant have considerable insecticidal efficacy in vitro against two test insects; Aphids and Mealy bugs.

(iv) Rotenone

This is a wide-spectrum botanical insecticide derived from the tropical legumes such as Lonchocarpus, Derris etc. [50;45]. Rotenone is the isoflavonoid in terms of chemistry. In respect to acute toxicity to mammals, natural rotenone is comparable to the traditional chemical pesticide DDT (rat oral LD50 is 132 mg/ kg) [45;51]. Derris spp., *Lonchocarpus spp.*, and *Tephrosia spp*. are used to make it.

Toxicological classification of pesticides

General the nomenclature for a variety of insect killers, wood preservatives, herb killers, rodent killers, chemicals used in the garden to kill pests, fungicides, and other chemicals use at home to destroy or repel unwanted organisms is known as 'Pesticides' [52]. Pesticides have different class owing to their differences their physical and chemical qualities. Therefore, it is important to classify them in respect to those qualities. Traditional chemical pesticides are substances created by man and do not naturally occur. Based on the need, they are categorized in numerous classifications. Drum in 1980 proposes three different classification methods for pesticides. These three common pesticide categorization approaches include:

(i). Classification due to mechanism of entry

(ii). Classification due to pesticide function and the pest organisms they act on, and

(iii). Classification due to pesticide chemical components [53].

A. Classification based on mode of entrance

This grouping involves categorizing pesticides by considering their entry points into the target organisms. Stomach poisons, systemic, contact, fumigants, and repellents are among them.

(i). Systemic pesticides

These are Pesticides that are taken by organisms thereby they are been transferred to untreated tissues are known as systemic pesticides. Systemic herb killers circulate across the plant and can get to parts of stems, leaves, and roots that have not been treated. They can eliminate weeds with only partial spray coverage. To destroy certain pests, they can effectively enter plant tissues and migrate with the aid of the plant vascular system. Several systemic insecticides are sprayed in order to control pests like lice, warble grubs, and fleas. Pesticide transport in plant tissues can be either one-directional or multidirectional. Migration of some pesticides takes place in one direction only within the plant, which could be either up or down, whereas others can only move upward directions, that is from root to leaves and will remain dormant if applied at the top of the plant. Furthermore, few pest killers are regarded locally systemic since they solely travel a short distance within a plant after contact. Typical examples of systemic insecticides are; 2,4-Dichlorophenoxyacetic acid and Glyphosate [54;55;56].

(ii). Non-systemic (Contact) pesticides

Contact pest killers are another name for Non-systemic pesticides since their actions are on pests.pesticides are most effective when they have direct contact with the pest. They penetrate epidermis when it touches the body of the unwanted organism and poisons it, killing it. These pesticides are likely not to penetrate plant tissues sometimes. Paraquat, diquat dibromide are typical examples of non-systemic insecticides [54;57].

(iii). Stomach poisoning and stomach toxicants

Pesticide that poisons the stomach enters the pest orally and through digestive system, poisoning it and causing death. During pests feeding processes they tend to ingest substances that poison the stomach, when they consume insecticides that have been sprayed to the whole crop. Basically the route of stomach toxins are; the mouth and digestive tract [57;58]. It can be best illustrated by controlling vectors such as bkack fly larvae or mosquito where toxic substances or bacteria are added to water where they dwell. The stomach of the larvae is destroyed by these insecticides, which kills the vector. Malathion is a good example.

(iv). Fumigants

Pesticides that kill or threaten to eliminate the unwanted organism through a process called fumigants. When these insect killers are used, they produce harmful fumes. These pesticides get into the unwanted organism as vapor through respiratory system and eventually kill them. Usually under high pressure, some of their active constituents are liquids, but becomes gaseous when released. When confined in a standard container, other active components are volatile liquids that are not constituted under pressure. They are used to kill unwanted organisms in vegetables, fruits, and cereals that have been preserved. They are also great for managing unwanted organisms in the farmland [55].

(v). Repellents

These are unpleasant substances that can efficiently put away pest from the agricultural products or areas applied but are not pests' killers. They also make it difficult for pests to locate crops.

B. Classification based on functions and pest specificity

Pesticides are classified using this method based on the target pest, and pest killing agents beget unique nomenclature to represent their action. These pesticides' numenclature are derived from "cide," in other words is "to kill" or "to eliminate" which come as a suffix to the numenclature of the unwanted organisms they eliminate. Eventually not all the pest killing agents have "cide." At the end of its nomenclature, Some are also categorized due to their intended use. Example, pests growth are either favoured or inhibit by growth regulators; defoliants cause plants to shade off their leaves; desiccants cause insects to dehydrate and die; repellents repel pests; attractants attract pests, usually to a trap; and chemosterilants (sterilize pests).

Some pesticides manage many insect classes and can be classified into multiple pesticide classes. Because it inhibits mites, insects, and nematodes, aldicarb, which is frequently used in citrus industry, might be classified as an acaricide, insecticide, or nematicide. 2, 4-D, which is a broadleaf herb killers [59;60]. The following is a list of their classifications:

C. Classification based on chemical composition

Chemical composition is a factor considered in Pesticides classification, which is the most common and useful way. Herbicides, fungicides, insecticides, and rodenticides are also categorized according to their chemical composition.

(i) Insecticides: Organophosphorus, Neonicotinoids (Imidacloprid), Carbamates, Organochlorine, Pyrethroids (permethrin), miscellaneous pesticides such as Antibiotics, Spinosyns , Benzolureas, and others are classified based on their chemical composition. They are further classified as indicated in Figure 1.

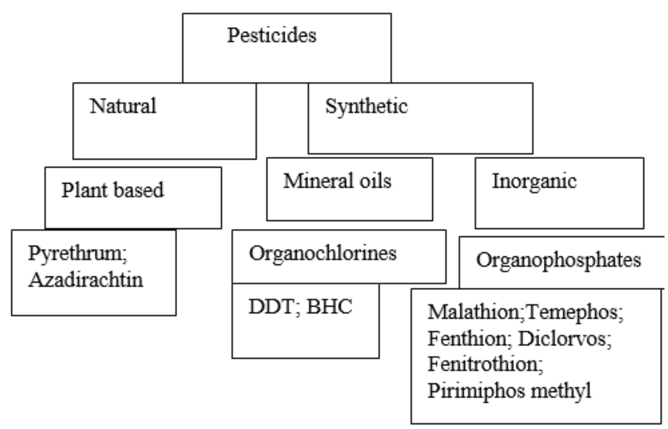

Fig. 1: Classification of insecticides [61].

(ii) Fungicides: They are divided into aromatic fungicides (chlorothalonil), amide fungicides (carpropamid), aliphatic nitrogen fungicides (dodine), dinitrophenol fungicides (dinocap), and dicarboximide fungicides (famoxadone), among others.

(iii) Herbicides: They are; 2, 4-D, chlorimuron, flufenacet, Paraquat, atrazine, and other herbicides.

(iv) Rodenticides: Rodenticide is divided into inorganic and organic rodenticides.

Classification based on mode of action

This is classed based on their mechanism of operation:

(i) **Physical poison**

These pesticides carried out its actions by exerting a physical influence on a single insect to eliminate it. Consider the following scenario: Clay that has been activated

(ii) **Protoplasmic poison**

The precipitation of protein is caused by these insecticides. Arsenicals are an example of this pesticide.

(iii) **Respiratory poison**

Chemicals that inactivate respiratory enzymes are known as respiratory poisons. Hydrogen cyanide is a good example.

(iv) **Nerves poison**

Chemicals block the transmission of impulses. Malathion is a good example.

(v) **Chitin inhibition**

This class of chemicals or pesticides act on the pest by inhibits the production of chitin in the unwanted organisms. Example: Diflubenzuron.

Classification based on sources

These are substances which could be biological or synthetic chemical that are employed to eliminate unwanted organisms and prevent them in causing damage. The major class of pesticides based on origin are; bio-pesticides and traditional chemical pesticides. Biological insect killers are host specific and are easily biodegradable unlike the chemically built insects' killers such as; Organochlorine, organophosphate, carbamate, and pyrethroid, that are persistence in the environment and are impact negative effects on other useful organisms. Natural sourced Pesticides such as plant, animal, and microorganisms are called biopesticides [35;61]. Therefore, bio-pesticides are classified into three categories as follows;

(i) **Microbial pesticides**

Fungi, Protozoa and bacteria are the main components in microbial pesticides. They carry out their actions on unwanted organisms by releasing poisons generated by microbials or infecting them. Two of the most often used insecticides in this category are; the toxic substances produced by *Bacillus thuringiensis* (Bti) and the active bacterium *Bacillus sphaericus*. The general mechanism of action involves the production of protein, which causes larvae starvation by binding to the larval gut receptor. A typical target for bacterial poisons is mosquito larvae and black fly larvae. Biochemical pest killer is generally less selective compare to microbiological insecticides [55].

(ii) **Plant incorporated protectants**

Plants naturally produce these insecticides. In addition, application of biotechnology aid in manipulation of gene necessary for producing pesticides in plant.

(iii) **Biochemical pesticides**

Biochemical pest killers are made out of components from nature with non-toxic pest/unwanted organisms management methods.

Classification based on toxicity and hazards

Toxicity of pesticide is basically ascertained by: amount or quantity (Dose) and duration or exposure frequency (Time) [59].

Acute Toxicity

Acute toxicity basically considers the degree of how toxic a pesticide is to biological organisms, following a single exposure in a short-term. Even if only a small amount is absorbed, pesticide with large degree of long-term exposure is deadly. Examples of toxicity with long-term exposure include; acute cutaneous toxicity, acute oral toxicity, and acute inhalation toxicity.

Chronic toxicity

This involves the nature of pest killers that is poisonous due to exposure to it for long duration. Due to the possible contact to pest killer on/in agricultural goods, and the environment, chronic toxicity of pest killers public health concern as well as those who work in close contact with pesticides [61]. Depending on the health risk linked with pesticides as well as pesticide toxic behavior. They are divided into four groups by the WHO [62]. The WHO categorized pesticides into two acute toxicity: oral and cutaneous, based on their experimentally generated lethal doses; dosage quantity needed to eliminate half of the experimental organisms either oral or dermal route. Recently, mostly used 'WHO recommended categorization of pesticides by hazard' recommends categorizing pesticides into 'specific WHO Hazard classifications.' WHO-conducted a study on rats and other laboratory animals in which they were given a pesticide dose orally and dermally. To arrive at this conclusion, they calculated the average lethal dosage or LD50 which causes half of exposed experimental organisms to die.

Table 1: WHO approved classification of Pesticides [63].

WHO Class		LD 50 for rats (Mg/kgbody wt.) Oral	Dermal	Examples
Ia	Extremely Hazardous	< 5	< 50	Parathion, Dieldrin, Phorate
Ib	Highly hazardous	5 -50	50 – 200	Aldrin, Dichlorvos
II	Moderately hazardous	50-2000	200-2000	DDT, Chlordane
III	Slightly hazardous	2000+	2000+	Malathion
U	Unlikely to present acute hazard	5000 or higher		Carbetamide, Cycloprothrin

Classification based on target range

Pesticides were divided into two categories using this approach of classification:

(A). Narrow or selective spectrum agents: They are effective against a small set of organisms with little or no effect on other organisms. For example, 2, 4-D impacts broad-leaved plants but grassland crops are not affected.

(B). Broad-spectrum agents: They are poisonous or effective against a majority of unwanted and wanted species. Possess poor selectivity ability in nature and frequently kill other species that are beneficial to the environment, including as birds, fish, reptiles, and pets. Chlorpyrifos and chlordane are two examples.

Classification based on biodegradability

Pesticides are also referred to as:

(i) Non-persistent: These are quickly decomposed into innocuous molecules by microorganisms and other living organisms after being released into the environment. Organophosphates, Pyrethroids, and insect repellents are examples.

(ii) Persistent: These are the ones that can take months or even years to break down. Examples are Organochlorines, DDT, etc.

Vegetables

The majority of vegetable definitions are not botanically based. Vegetable classifications are, by their very nature, arbitrary, and are frequently based on usage rather than plant morphology. A vegetable, for example, is an herbaceous crop or piece of a plant that is consumed whole or in part, uncooked or cooked [64], usually not as dessert. Watermelon and rhubarb are all vegetables that are widely eaten as desert. Mushrooms are fungus, not plants, but they are commonly thought of as vegetables. Vegetables are a type of horticulture crop that is grown for human use. Small fruits and tree fruits, which are frequently planted as perennials, are other horticultural food crops. Annual or perennial vegetable crops are available. A vegetable crop can be defined as a high-value crop that is actively managed and requires specific after-harvest care from a production standpoint [65].

Vegetables are a vital element of our daily nutrition, and the market is brimming with them. Veggies are high in minerals and vitamins and are naturally excellent for you. They aid in the prevention of cancer, diabetes, and heart disease in our bodies. Almost all of the vegetables are low in fat and calories, contain no cholesterol, and are high in fiber. Vegetables include a lot of fiber, which keeps your digestive tract healthy and helps you avoid constipation. Because vegetables are low in calories, we can consume a lot of them without spending too much energy. Vegetables contain a variety of vitamins and other substances that supply nourishment to the body. Essential amino acids, which are necessary by the organism for living, are found in vegetables [66].

Types of vegetables

There are numerous types and varieties of vegetables, all of them being the power house of nutrients, minerals and vitamins. They includes; Green leafy vegetables, Bulb and stem vegetables, Root and tuber vegetables, Fruit vegetables, and Edible flowers vegetables [65;66].

Pesticides and agriculture

In many parts of the world, agricultural development has a lengthy history. Agricultural activity originated some 10,000 years back in Mesopotamia, which roughly corresponds to recent time Iraq, Turkey, Syria, and Jordan [68]. Occupants in these places harvest edible seeds by cultural burning and cool burnig farming and cohabitation gardening, among other methods. Lentils, barley, wheat, peas, were farmed in huge quantities as the number settlers grow and lived on farms [69].

Davies (1968) also claims that around 7500 years back, several native crops were domesticated separately in West Africa, New Guinea, and Ethiopia. China was the first country to domesticate rice and millet [70]. Corn, squashes, potatoes, and sunflowers were all domesticated independently in America [69]. Pests, weeds, and diseases frequently attack cultivated crops, resulting in significant agricultural output losses. Without pesticides, losses of fruits, vegetables, and cereals would be as high as 78 percent, 54 percent, and 32 percent, respectively, due to pests and illnesses [71].

Pesticides residues in vegetables

In other to decrease insect and disease losses, vegetable farmers use a variety of pesticides at various doses. Despite pesticides' benefit to agricultural productivity, data from other studies revealed the availability of pesticide residues which may be harmful to man's health and ecological environment [72].

As long as the climate permits, most vegetables are now cultivated all over the world [25]. Pesticide residues observed most frequently in agricultural products from farms are pesticides which are administered to the vegetables purposely to combat diseases infected organisms [27]. Only 15 percent of the pesticides used to kill pests and pathogens reach their intended targets, with the remaining 85 percent ending up in the environment [28]. In addition, improper execution of dangerous chemical and pesticide restrictions, as well as a lack of technical know-how among farming communities, leaves the majority of pesticide active components in vegetables.

Pesticide residues accumulation are been influenced by the physiochemical features of pesticide molecules [73]. The residues of Pesticide are frequently found in vegetables after harvest due to the application of pesticides at various stage of cultivation. The large usage of pesticides by most farmers and commercialists on multiple cases especially at the growing process of crops is due to the fact that they limit the amount of toxic substances generated by pests, boost production, with low man-power needed. As a result of these farmers' pesticide use attitudes, residual pesticide are retained in vegetables and other agricultural commodities [74].

Impacts of pesticides in agriculture

Several types of pesticides have provided various primary benefits in a so many areas, including public health and agricultural activity [75]. In agricultural productivity, pesticides are a must. Pesticides are used by agriculturist to manage unwanted species in agricultural operations, consequently increasing agricultural products yield.

With no commensurate increase of agricultural goods production, the twentieth century would have experienced an exploded global population. Pesticides play a vital role by curbing poor harvest which is a product of activities of pests, weeds and diseases. Several factors contribute to the improvement in agricultural products yield; pesticides are also a key player [75]. About one-third of agricultural products employed pesticides in one stage of its production. There would be loss of more than half of vegetable, if pesticides were not employed in its stages of production [76]. This fact made pesticides a vital commodity in lowering illnesses and increasing crop yields around the world. Therefore, they have made a considerable contribution to reducing hunger and increasing availability to high-quality food.

Pesticide use has a secondary benefit that is based on perception, but has long-term effects, such as increased cultivation and agribusiness revenues, improved nutritional value and consequently health, food quality and improved life quality and expectancy [77;78]. Another example is that enhanced agricultural output through the use of appropriate pesticides could greatly increase the income of farming families [69].

Pesticides and environment

Pesticide use is gaining popularity due to increase in human population and climatic changes, and future world pest killing chemicals production is expected to increase. Although pesticides play a vital role in enhancing crop yields and producing affordable, high-quality food, their widespread usage has a numerous detrimental consequences to human health and consequently to the ecosystem [79]. Because pest killers are employed to eliminate and control unwanted organisms due to their chemical constituents, which also exert toxicity to other species and environment [75;80;81;82]. In addition, environmental pollution is one major challenge of pesticide usage, as the contamination spreads away from the target plants. Pesticides can travel by wind current, leaching through the air to the water, and to plants, animals, and humans [83;84].

Impact on soil

A function of soil is it's to sieving characteristics, breakdown, and ability to remove toxins pest killing components [85]. Consequential degradation of pesticide produces residues that survive and alter for long period not just in aquatic environments but also in terrestrial environments, posing harm to the environment [86]. Indeed, pesticide contamination of soil and sediment has been a prevalent concern in terrestrial areas, with negative consequences for food quality and agricultural balancing [87].

The persistence of pesticides in the soil is strongly correlated with their properties such as; solubility in water, soil sorption constant (Koc), octanol/water partition coefficient (Kow), and half-life in soil (DT_{50}) [88]. For pest killers that are firmly attached to soil, high Kow values translate into high Koc values, and these characteristics lead to higher sorption to organic matter in the soil. Pesticides that are not water soluble and persistent in nature are more likely to bioaccumulate in soils. [75;89]. Pesticides that have high affinity to soil particles have consequently been phased out in major nations [90]. Other pesticides, such as fungicides, carbamates, and some organophosphorus insecticides, are not persistent in soil, although they can go through distinct processes during runoff and leach into other media. As a result, pesticide-contaminated soil poses a significant danger to water and the food chain.

Pesticide transformation behaviors in the soil are basically determined by its chemical and physical properties. Pesticide adsorption increases with increasing organic matter concentration [90;91;92;93].

Impact on water

Many substances were discovered in surface water and groundwater, including certain insecticides [83]. Pesticides are widely accepted to enter both groundwater and surface water through anthropogenic activities [91;92].

Pesticides gotten from polluted groundwater, laundry sites, and refuse dump places, [94]. Surface water systems, such as rivers, lakes, streams, reservoirs, and estuaries, are particularly sensitive to pesticide and other chemical accumulation because they are small captive sinks of human activity by-products [95]. The hydrologic cycle connects topsoil water systems to both beneath soil and atmospheric water. Pesticides in topsoil level water can also be transmitted to beneath soil water through soil. Evaporation and transpiration also allow them to enter the atmosphere [96]. Surface waters can be recharged by atmospheric and groundwater.

The mobility of pesticides in water leads to pesticide pollution of water resources [84]. Pesticide pollution of surface water and groundwater is a severe and urgent problem in freshwater and coastal ecosystems all over the world [75; 92; 97]. Furthermore, is almost impossible to clean polluted surface water, particularly polluted groundwater, due to high costs and technological constraints [75;98]. There have been numerous cases of pesticide contamination of both topsoil water and beneath soil water around the world [99; 100].

Impact on air

Air contamination by pesticide is a significant pollution factor which has harmful effects on plants and animals as well as human health [101]. Pest control agents employed in farm purposes often escape into atmosphere, and pesticide residuals in the atmosphere are primarily due to pesticide that escapes from the plants, soil and water during application [102]. Pesticide sprays are one way to apply pesticides. They are primarily ejected as water droplets by a fan and, following unsettled condition as they pass through the covering, are driven into beneath soil by gravitational force and moved by activities in the atmosphere such as wind [103]. Subsurface application, surface application, and aerial spraying are three common spraying techniques employed in today's agricultural development. Hand spraying, on the other hand, is still common in many impoverished countries [104].

All pesticide spraying methods have the potential to be ineffective, pollute the air, and expose the general people to pesticides [75]. Pesticide residues are released, diffused, and carried over numerous distances, causing environmental recycling process that occurs between the atmosphere and the terrestrial environment [105;109]. Pesticide loss during drifting processes is approximately 2% to 25% [110]. This practice not only pollutes the local ecosystem, but it also has negative consequences for the worldwide environment [109]. Pesticides such as toxaphene and its likes were employed in fields in the America, where they were carried by atmospheric processes, settle down in cooler regions, and deposited from the atmosphere onto Canada's Great Lakes [111]. As a result, determining the extent of pesticide-related air pollution is difficult.

Impact on food safety

Pesticide actions such as its volatility to other areas where not needed such as water, atmosphere, non- targeted species contributes to food and environment contamination [91;112]. Pesticides and their residues' environmental behavior results in food contamination and plant harm. Pesticide residues in agricultural goods have long been a source of worry, particularly in fresh fruits and vegetables [113]. Pesticide residue exposure via the meal is thought to be up to five times more than exposure from other pathways including drinking water and air [113]. Plants are harmed indirectly by pesticide use because chemicals destroy soil microbes and helpful insects.

Impact on non-target organism

On spraying pesticides to target plants, non-target creatures are negatively impacted, unlike the targeted insect pests [114]. Injurious to aquatic environments, beneficial insects, animals and birds, as well as natural opponents of insect pests, is included in this category. Non-target organisms are endangered by pesticides in two ways: firstly, it causes damages to beneficial organisms by physical contact, and secondly, the residual pesticides may possess deleterious effects on beneficial species in a distance time [75].

Pesticides mode of actions in plants

Herbicides kill plants in a variety of ways since they are designed to target certain metabolic pathways of plants e.g. respiration, photosynthesis, plant hormone activity, etc [115]. Herbicide must make touch with the weed's site of action; otherwise, the herbicide's effects will be ineffective. Herbicides can influence a variety of plant sites, and each herbicide has its own mechanism of action at the site of action; for example:

Inhibitors to photosynthesis

These herbicides (e.g. triazines, copper-containing insecticides) disrupt biomembranes with highly active chemicals, preventing photosynthesis. An accumulation of highly reactive chemicals destroys cell membranes, causing the plants to die. Triazine herbicides, such as simazine and atrazine are effective and low-cost herb killers that are employed for managing a variety of large leaf unwanted plants and selected grasses [116]. Atrazine, for example, limits electron transport in photosystem II by competing with plastoquinone II at its binding site and inhibiting photosynthesis [117].

This inhibition causes carbohydrate synthesis to stop, resulting in a decrease in the carbon level and a accumulation of CO_2 within the plant cell [118]. Copper or copper-containing insecticides can disrupt electron transport via photosystem II at high concentrations. Copper ions prevented electron donation from Tyrz to P680, according to research. The central manganese atom of chlorophyll was found to be substituted by ions of mercury, copper, or cadmium, restricting the function of the photosystem [119]. It has been demonstrated that copper ions can oxidize the low potential form of cyt b559 at low concentrations. The low potential form of cyt b559 was observed to be oxidized by copper ions at low concentrations (1–10 M), and the high potential form was oxidized at higher concentrations (10–100 M). This is most likely because the labile cyt b559 form was deprotonated [120].

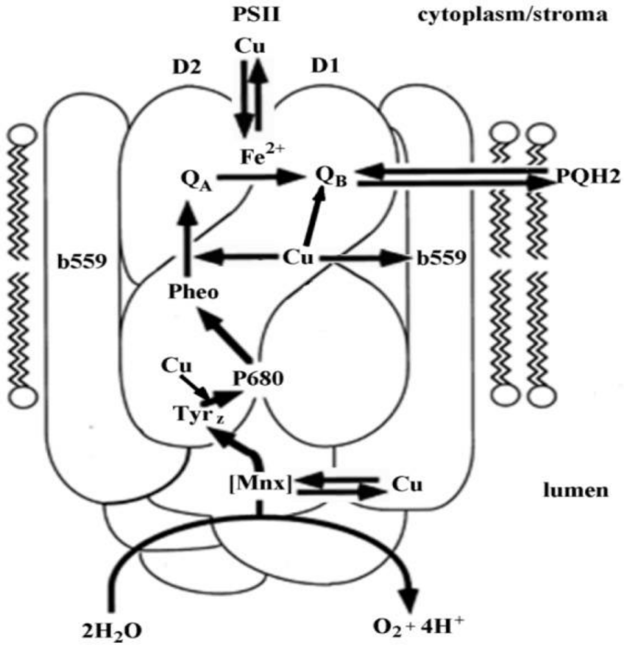

Fig 2: Pathway of inhibitory action of pesticides on photosynthesis in plants [117].

Mitochondrial respiration inhibitors

By restricting electron transfer at the ubiquinol oxidizing or Qo site of the cytochrome bc1 complex between cytochrome b and cytochrome c1, azoxystrobin inhibits mitochondrial respiration and energy production and prevents the generation of ATP [121].

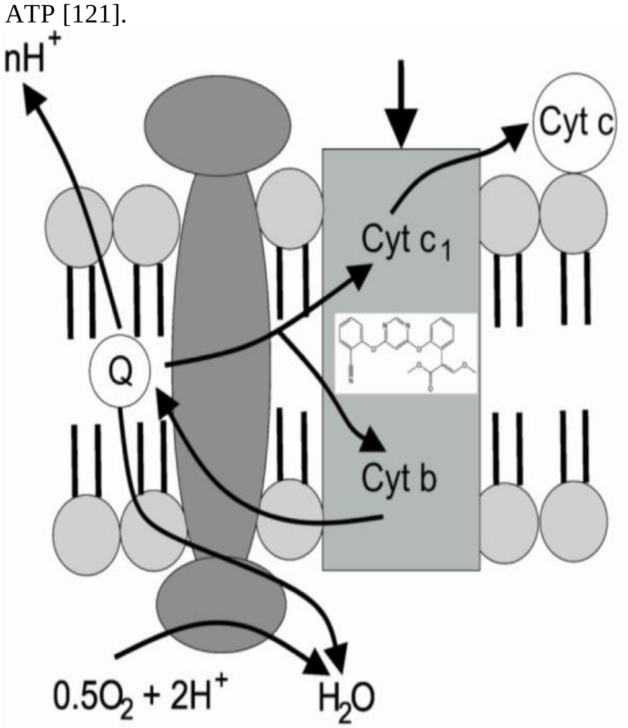

Fig 3: Pathway of inhibitory action of pesticides on mitochondrial respiration in plants [117].

Regulators of growth

Herbicides of this type are used to manage broadleaf unwanted plants. They influence plants by boosting their development in the same way as natural hormones do, resulting in a shift in hormone balance. This group includes 2,4-dichlorophenoxiacetic acid, for example. The auxin-like capacity of 2,4-D is thought to be the mechanism for its herbicidal activity. Auxin receptors have been found to identify synthetic auxin analogues like 2,4-D [122].

Pesticides mode of action in animals

Neurological system is the primary endangers system for organochlorine pesticides' long-term harmful effects. Because of their extended environmental persistence, these compounds are active ingredients in many household products, so also as many agro-based and environmental pest management treatments [118]. Organophosphorus insecticides are irreversible inhibitors of acetylcholinesterase (AChE), therefore, they are potential neurotoxins [123].

Acetylcholinesterase inhibitors (AChE)

Acetylcholinesterase catalyzes acetylcholine breakdown in the synapse. AChE is required for normal sensory and neuromuscular function because it prevents continuous nerve firing by deactivating acetylcholine, thereby hydrolysis to choline and acetate, at the nerve ends. Pesticides containing organophosphates phosphorylate acetylcholinesterase, lowering its activity. Acetylcholine builds up in the nervous systems (i.e central and peripheral), as a result. Such inhibitory activity causes a buildup of acetyltocholine in synapses, causing nerve function to be disrupted and the organism to die [117].

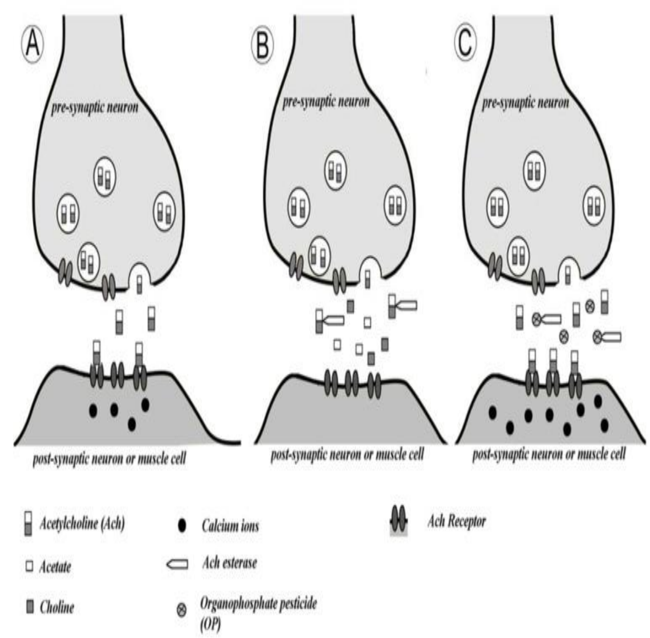

Fig 4: Inhibitory action of pesticides on Acetylcholinesterase in synapse of nerve cell of animals [117].

Carcinogenic, teratogenic, and genotoxic effects of pesticide exposure

Researches involving animals are still a useful technique for discovering potential cancer risks in humans. Research data indicating a higher incidence of malignant tumors in numerous species and by several channels is regarded sufficient prove showing that chemical causes cancers in research organisms [118]. Some pesticides, such as dithiocarbamates, have been shown to be carcinogens in animals. The main concern of these poisons is the development of carcer causing compounds such as N-nitrosocarbaryl, a derivative of carbaryl that is a powerful carcer in rats [118].

It has been determined that ethylene thio-urea, a byproduct of ethylene-bis dithiocarbamate fungicides, is a teratogen, goitrogen, and carcinogen that can affect thyroid function and is associated with thyroid cancer in animals. [121]. Increased levels of thyroid-stimulating hormone, and lower levels of T4 (serum thyroxin) due to larger thyroid mass, were reported in subchronic level investigations of metiram-treated rats, indicating that fungicides have thyroid-like effects. Because of their metabolite ETU, ethylene-bis dithiocarbamates are deemed carcinogenic in general [121]. In vitro tests of zineb's effects on human lymphocytes cells revealed DNA strand breaks, implying that the afflicted cells could become carcinogenic if they survived and multiplied [124]. In rat fibroblasts exposed to mancozeb, observed DNA single-strand breaks. Atrazine is a common triazine herbicide that is used in enormous quantities all over the world. It has been identified as a potential carcinogen and an endocrine disrupting agent [124]. Female rats given atrazine developed breast tumors, which have been recorded [125].

Compounds that cause direct or indirect DNA damage are known as genotoxic [118]. Many pesticides examined caused a variety of mutations as a result of DNA damage. Agrochemical components have a modest genotoxic potential, but work related exposure to pesticide combinations has been linked to favor genotoxic destructions in several research findings [124]. Pesticides such as chlorothalonil fungicide is said to be responsible for loss of embryo in pregnancy condition, anemia, kidney destruction, destruction of liver, oxidative damage of kidney and DNA and stomach malignancies in laboratory testing [125].

The majority of these effects have been reported in various animals that have been tested. As a result, the United States has classified chlorothalonil as a "probable human carcinogen" [126]. It is well recognized that pesticide-induced oxidative stress causes genotoxicity [127]. Pesticides have been demonstrated to disrupt cellular redox equilibrium by increasing lipid peroxidation, reactive oxygen species (ROS), and antioxidant defense depletion [128; 129; 130]. Different strategies exist for biological species to prevent themselves from substances that genotoxic and carcinogenic. GSTs are a class of enzymes that conjugate GSH to xenobiotics in their natural or altered forms, and they may protect organisms from external and endogenous toxins [131]. Pesticide exposure can change the activity of these enzymes in many circumstances [132; 133].

Pesticides regulations and public health

The World Health Organization maintains a program that propagate and coordinates pesticide usage guidelines, policies, and strategies, in public health, including pesticide specifications, safety concerns, and effectiveness. The majority of wealthy countries had implemented these strategies and seen significant improvements in public health. United States in 1947 began pesticide regulation with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which promoted pesticide industrial production, usage, and distribution. Before 1970, when the Environmental Protection Agency (EPA) took over pesticide regulation and registration, after the FIFRA was revised multiple times. Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the Environmental Protection Agency (EPA) is in charge of regulating pesticides with public health applications and ensuring a safer ecosystem. The EPA can establish, modify, or revoke acceptable pesticide residue levels in foods under the Federal Food, Drug, and Cosmetic Act (FFDCA). The US Food and Drug Administration (FDA) ensure that pesticide residual levels in foods do not exceed those set by the Environmental Protection Agency (EPA) [134].

Before being utilized, all pesticides sold in the United States must be licensed by the Environmental Protection Agency. Tolerance or threshold thresholds for permissible pesticide residues in foods such as milk have also been established by regulatory agencies. The Canadian Food Inspection Agency (CFIA), which is overseen by the Minister of Agriculture and Agro-Food, is in charge of conducting inspections and enforcing federal food safety regulations. The Pest Management Regulatory Agency (PMRA), which is part of the Department of Health, is responsible for reducing pesticide risks to human health, safety, and the environment. The National Agency for Food and Drug Administration and Control (NAFDAC) in Nigeria is in charge of establishing and enforcing strict adherence to pesticide registration and usage rules. The European Commission established maximum residue levels (MRLs) to ensure that pesticide residues are not discovered in food or feed at levels that pose an unacceptable danger to human consumption [135]. Pesticides in or on food or feed have upper legal concentration limits known as MRLs. They apply to a wide range of plant and animal-based food commodities, and they usually apply to the product as it is placed on the market. Many Central and South American countries have implemented pre-inspection systems that incorporate farm-level Integrated Pest Management (IPM) as well as post-harvest monitoring. These programs aid in ensuring that food reaches customers with minimal pesticide residues. However, for the thousands of small farmers engaged, such schemes are extremely difficult to implement [136].

Effects of pesticides on human health

Residues of pesticides can be hazardous to humans, thus they must be handled carefully and thrash appropriately. The general public is exposed too much lower levels of pesticide residues through food and water when they are not in a region where pesticides are utilized. Crop growers employ a variety of insecticides at various doses to decrease pest and disease losses. Despite the widespread use of pesticides by farm households, substantial worries have been raised regarding the health dangers posed by exposure to pesticides during chemicals mixing and application, working in farmlands treated with pesticides, and residues deposition on agricultural products and in water for the general public [137;138].

Despite that fungicide acute toxicity is low in human, but can irritate the skin and eyes. Inhaling these pesticides' spray mist or dust might cause throat irritation, sneezing, and coughing. Chronic exposure to low levels of fungicides might have deleterious health consequences. The majority of human fungicide poisonings have occurred as a result of seed grain intake.

Generally herbicides have a low acute toxicity to people since plant physiology differs so much from human physiology. There are exceptions; many might irritate the skin because they are often powerful acids, amines, esters, and phenols. Coughing and a burning sensation in the nasal passages and chest may occur after inhaling spray mist. Dizziness can occur as a result of prolonged inhaling. Vomiting, a burning sensation in the stomach, diarrhea, and muscular twitching are common side effects of ingestion [138].

The most common type of pesticide toxicity is insecticide poisoning. The most harmful pesticide poisonings are caused by pesticides with carbamate and organophosphate ingredients. Examples of organophosphate pesticides include carbofuran, methomyl, chlorpyrifos, diazinon, dimethoate, disulfoton, malathion, methyl parathion, and ethyl parathion. Chemicals called carbamates include carbaryl and oxamyl. By preventing the enzyme cholinesterase from functioning, organophosphates and carbamates have an impact on the nervous system. Any organism with cholinesterase in its nervous system, such as insects, fish, birds, humans, and other mammals, is poisoned by these substances.

One must first understand how the nervous system works in order to understand how organophosphate and carbamate pesticides affect the nervous system. The nervous system, which includes the brain, is the most intricate system in the body because it involves millions of cells cooperating to create an internal communications network. Through this complex network of cells, messages (stimuli) or electrical impulses (messages) are transmitted. There is a space between nerve cells or neurons called a synapse instead of their actual physical contact. The impulses must pass across or "bridge" the synapse between nerve cells in order to maintain message transmission throughout the entire network.

The chemical acetylcholine is released when an impulse hits the synapse, carrying the message to the next cell. Acetylcholine is the major molecule involved in the transmission of nerve impulses between two neurons' synapse. The enzyme cholinesterase breaks down acetylcholine after the impulse has been passed across the synapse. The synapse is then "cleared" and ready to accept another transmission.

The activity of cholinesterase is inhibited by organophosphate and carbamate pesticides, resulting in a buildup of acetylcholine in the body. When acetylcholine levels rise, neuronal communications between nerve cells become uncontrollable. The nervous system gets "poisoned," as acetylcholine builds up in the synapses, causing continuous transmission of impulses [137;138].

Acute effect

Exposure to pesticides through any route; oral, dermal, ocular and inhalation causes severe effects. Acute disease often develops almost immediately after contact or exposure to the chemical. Acute ailments in people is caused by pesticide drift from agricultural fields, pesticide exposure during application, and purposeful or inadvertent poisoning [139;140]. Pesticide poisoning can result to several symptoms including skin rashes, headaches, poor focus, nausea, dizziness, impaired eyesight, cramping, whole body pain, and in severe cases, coma and death. Every year, about 3 million cases of acute pesticide poisoning are recorded around the world. About two million pesticide poisoning cases in humans are mostly self-ingestion to commit suicide, with the rest being occupational or accidental poisoning [141].

Chronic effect

Chronic consequences are any negative effects that result from modest dosages reoccurrence over time, such as birth defects, fetal toxicity, and the buildup of benign or malignant tumors, genetic changes, blood problems, nerve disorders, endocrine disruption, and reproduction effects. Laboratory analysis cannot easily give details distinction between pesticide’s chronic toxicity and acute toxicity. A repeated exposure to pesticides residues or toxic components in a long-term range results in chronic disease in humans [142]. Symptoms do not show right away, although they do appear later. Agricultural farmers, in particular, are at a higher risk of being harmed. However, the general public is also at risk, particularly as a result of pesticide residues in food (vegetables) and water, or pesticides drifting from fields [142]. Several recent studies have found a relationship between pesticide exposure and the occurrence of chronic disorders of the neurological, reproductive, renal, cardiovascular, and respiratory systems in humans.

Maximum pesticides residues levels

Pesticide residues are held to different standards in different countries, and monitoring their presence is done in different ways. Certain pesticides have no maximum residual levels in some nations, despite the fact that they are known to be toxic when swallowed [143]. An Acceptable Daily Intake (ADI) value is calculated on a foundation built on science for each pesticide and relates to the chronic risk. The ADI is the maximum quantity of possible residue that can be consumed by a single individual every day of their lives without causing a health risk [14]. This is determined by multiplying the "No observed adverse effect levels" (NOAELs) from long-term toxicological testing by a high safety factor, usually 100. A NOAEL is the maximum dose that has no negative side effects. Acceptable Daily Intake cannot be exceeded because of the Maximum Residue Levels (MRLs). Maximum Residue Levels are the pesticide limits that are allowed in food, and they are defined separately for each chemical and crop. MRLs are trading standards, not safety limits, and are used to ensure that good agricultural practices are followed in order to preserve ecosystem and human health. As a result, an MRL exceedance does not imply a safety problem, because residues in food must be proven to be safe. The goal of the pesticide business and the agriculture sector is to keep residues to a minimum and avoid exceeding the MRL at all costs [143; 144].

Conclusion

Pesticides have shown to be of great importance to agriculturist and humanity globally, enhancing food productivity and delivering many indirect benefits to society. The excess human intake of chemicals contain in pest killers which accumulate in vegetables as pesticide residues led to several hazardous conditions in human, including damage to central and peripheral nervous systems, and other disorders. The persistence of pesticides in the ecosystem as a result of human activities or planned application has harmed ecosystems and beneficial organisms. It is vital to curtail the use of pesticides or employed less harmful compounds. Stepping up the incentives for safe agricultural practices, by encouraging research on crops and animals production which have less deleterious effects to the environment and public health is very vital. Understanding the biochemical mode of actions of pesticides is very vital. Consumption of food (Vegetables) with pesticides residues, chemical accidents, and occupational exposure in agriculture are the most common causes of acute and chronic pesticide poisoning.

References

[1] Maton, S.M.; Dodo, J.D.; Nesla, R.A. and Ali, A.Y. (2016). Environmental Impact of Pesticides Usage on Farmlands in Nigeria. International Journal of Innovative Research & Development. 5: 4.

[2] Fernando, P.C. (2017). Pesticides, environment, and food safety. Food and Energy Security, 6(2): 48–60.

[3] Ananda, G.; Kesava, R.A. and Ramesh, H.L. (2020). Analysis of pesticide residues in carrot retailed in vegetable markets in five districts of Karnataka, India. GSC Biological and Pharmaceutical Sciences, 10(03):027–038.

[4] Emmanuel, C. O.; Otitoju O.; Moses A. A.; Ozioma P. E.; Bando C. D. and Zephaniah H. S. (2021). Ecological risk assessment of pesticide residues in fish samples from river Donga in Donga, Taraba state, Nigeria. *International Journal of Biochemistry, Bioinformatics and Biotechnology Studies.* 6(2):1-8.

[5] Jenner, P. (2001). Parkinson's disease, pesticides and mitochondrial disfuntion. Trends in Neuroscience, 24:245-246.

[6] Ojajarvi, I.; Partanen, T.; Ahlbom, A.; Boffetta,P.; Hakulinen, T. and Jourenkova, N. (2000). Occupational exposures and pancreatic cancer: A meta-analysis. Occup. Environ. Med., 7:316-324.

[7] Ritz, B. and Yu, F. (2000). Parkinson's disease mortality and pesticide exposure in California 1984-1994. Int J Epidemiol, 29:323–329.

[8] Figa-Talamanca, I.; Traina, E. and Urbani, E. (2001). Occupational exposure to chemicals: recent evidence on male reproductive effects and biological markers. Occup Med (Lond), 51:174–188.

[9] Bando, C. D., Tutuwa A. J., Ogu, E. O., Nuhu, I. and Mbaragbog, S. J. (2020b). Phytochemical screening, proximate nutritional analysis and anti-nutrient analysis of tiger nut (Cyperus esculentus). *International Journal of Advanced Scientific Research*. 5(4):53-60.

[10] Gupta, A.; Singh, B.; Parihar, N.S. and Bhatnagar, A. (1998). Pesticide residue in the farm gate samples of bottle gourd, cauliflower, cabbage and fenugreek at Jaipur. Pesticide Research Journal, 10: p.86-9.

[11] Banerjee, B.D.; Seth, V. and Ahmed, R.S. (2001). Pesticide-induced oxidative stress: perspectives and trends. Rev Environ Health. 16:1-40.

[12] Panemangalore, M.; Dowla, H.A. and Byers, M. (1999). Occupational exposure to agricultural chemicals: effect on the activities of some enzymes in the blood of farm worker. Intl. Arch. Environ. Hlth. 72(2):94–98.

[13] Rajveer, K.; Gurjot, K. and Shweta, R. (2019). Pesticides Classification and its Impact on Environment. International Journal of Current Microbiology and Applied Sciences. 8:3.

[14] WHO. (1990). Public health impact of pesticides used in agriculture. World Health Organization, Geneva.

[15] Bando, C. D., Tubasen, H. N., Nuhu, I., Ogu, E. O. and Madukwe, S. O. (2020a). Hypolipidemic effect of the crude ethanolic extract of thymus vulgaris in rats fed with lipid. *International Journal of Advanced Scientific Research*. 5(4):4-10.

[16] WHO. (2012). The WHO recommended classification of pesticides by hazard and guidelines to classification. World Health Organization, Geneva.

[17] Nabil, E-W.; Shehata, S.; Gehan, A. and Ahmed, S. (2013). Pesticide-Residue Relationship and Its Adverse Effects on Occupational Workers. http://dx.doi.org/10.5772/54338.

[18] Ojo, J. (2016). Pesticides use and health in Nigeria. Ife *Journal of Science*. 18:4.

[19] Frederick, A. A. (2011). Assessment of Pesticide Residues in Vegetables at the Farm Gate: Cabbage (Brassica Oleracea) Cultivation in cape Coast, Ghana. Research Journal

Environmental Toxicology, 5(3):180-202.
[20] Mohammed, M. A.; Elbashier, X. S.; Alnail M.; Albashir A.S.A. and Bashir, H.O. (2016). Effect of Pesticide Residues (Sevin) on Carrot (Daucus carota L.) and Free Nitrogen Fixers (Azotobacter spp). Journal of Agricultural Sciences, 7:93-99.
[21] Rohan, D.; Siddharth, T. and Padmaja, N. (2012). Pesticide residue analysis of fruits and vegetables. Journal of Environmental Chemistry and Ecotoxicology. 4(2):19-28.
[22] Köhler, H.R. and Triebskorn, R. (2013). Wildlife ecotoxicology of pesticides: can we track effects to the population level and beyond?. Science, 341:759–765.
[23] Paoli, D.; Giannandrea, F.; Gallo, M.; Turci, R.; Cattaruzza, M.S.; and Lombardo, F. (2015). Exposure to polychlorinated biphenyls and hexachlorobenzene, semen quality and testicular cancer risk. J. Endocrinol. Invest. 38:745–752.
[24] WHO.(2017). Agrochemicals, health and environment: of resources Available at http://www.who.int/heli/risks/toxics/chemicalsdirectory/en/index1.html.
[25] Kithure, J.G.N.; Murung J.I.; Tum, P.K.; Wanjau, R.N. and Thoruwa. C.L. (2017). Fate of Lambda Cyhalothrin in Kales, Tomatoes and Cabbage from Rural setting in Kenya. International Journal of Scientific Research and Innovative Technology.Vol. 4:2.
[26] Obida, M.; Stephen, G.; Goni, S. H. and Victor, O. O. (2012). Pesticide Residues in Bean Samples from Northeastern Nigeria. ARPN Journal of Science and Technology.
[27] Erhunmwunse, N.O.; Dirisu A. and Olomukoro, J.O. (2012). Implications of Pesticide Usage in Nigeria. Tropical Freshwater Biology, 201221 (1):15-20.
[28] Moses A. A.; Otitoju O.; Emmanuel, C. O.; Ozioma P. E.; Bando C. D. and Zephaniah H. S. (2021). Determination of selected pesticide residues in leafy vegetables (amaranthus spinosus) consumed in Donga, Taraba state. *International Journal of Biochemistry, Bioinformatics and Biotechnology Studies.* 6(2): 9-16.
[29] Guler, G.O.; Cakmak, Y.S.; Dagli, Z.; Aktumsek, A. and Ozparlak, H. (2010). Organo-chlorine pesticide residues in wheat from Konya region, Turkey. Food Chem. Toxicol., 48:1218–1221.
[30] Donkor A, Osei-Fosu P, Dubey B, KingsfordAdaboh R, Ziwu C, Asante I. 2016. Pesticide residues in fruits and vegetables in Ghana: a review. Environ. Sci. Pollut. Res. Int., 23(19):18966-87.
[31] Dasika R.; Tangirala S. and Naishadham, P (2012). Pesticide residue analysis of fruits and vegetables. J. Environ. Chem. Ecotoxic. 4(2):19-28.
[32] Keikotlhaile, B.M. and Spanoghe P. (2011).Pesticide Residues in Fruits and Vegetables. http://cdn.intechopen.com/pdfswm/13013.pdf
[33] Cimanga, K.; Kamba, K.; Tona, L.; Apers, S.; De Bruyne, T.; Hermans, N.; Totte, J.; Pieters, L. and Vlietinck, A.J. (2002). Correlation between chemical composition and antibacterial activity of essential oils of some aromatic medicinal plants growing in the Democratic Republic of Congo. J. Ethnopharm. 79:213–220.
[34] Grdisa, M. and Grsic, K. (2013). Botanical Insecticides in Plant Protection. Agriculturae Conspectus Scientificus, 78 (2):85 – 93.
[35] Dimetry N.Z. (2014). Different Plant Families as Bioresources for Pesticides. In: Advances in Plant Biopesticides. D. Singh (Ed.), Springer India.
[36] Campos, E.V.R.; De Oliveira, J.L.; Pascoli, M.; De Lima, R.; Fraceto, L.F. (2016). Neem oil and crop protection: From now to the future. Front Plant Sci., 7:1494.
[37] Chengala, L. and Singh N. (2017). Botanical pesticides – a major alternative to chemical pesticides: A review. Int. J. of Life Sciences. 5 (4):722-729.
[39] Koul, O.; Singh, G.; Singh, R.; Singh, J.; Daniewski, W.M. and Berlozecki, S. (2004). Bioefficacy and mode of action of some limonoids of salannin group from Azadirachta indica A. Juss and their role in a multicomponent system against lepidopteran larvae. J. Biosci. 29:409 – 416.
[40] Sola, P.; Mvumi, M.; Ogendo, J.O.; Mponda, O.; Kamanula, J.F.; Nyirenda, S.P.; Belmain, S.R. and Stevenson, P.C. (2014). Botanical pesticide production, trade and regulatory mechanisms in sub – Saharan Africa: making a case for plant based pesticidal products. Food Sec.
[41] Brahmachari, G. (2004). Neem – an omnipotent plant: a retrospection. Chembiochem. 5: p.408–421.
[42] Isman, M.B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu. Rev. Entomol., 51:45–66.
[43] Batish, D.R.; Singh, H.P.; Setia, N.K.S and Kohli, R.K. (2006). Chemical composition and phytotoxicity of volatile essential oils from intact and fallen leaves of Eucalyptus citriodora. Z. Naturforsch. 61: 465–471.
[44] Su, Y.C.; Ho, C.L.; Wang, I.C.; Chang, S.T. (2006). Antifungal activities and chemical compositions of essential oils from leaves of four eucalypts. Taiwan J. For. Sci., 21:49–61.
[45] Batish, D.R.; Singh, H.P.; Kohli, R.K. and Kaur, S. (2008). Eucalyptus essential oil as a natural pesticide. For. Ecol. Manag., 256:2166 – 2174.
[46] Koul, O.; Waliai, S. and Dhaliwal, G.S. (2008). Essential oils as green pesticides: potential and constraints. Biopest. Int. 4 (1):63 – 84.
[47] Mukanga, M.; Deedat, Y. and Mwangala, F.S. (2010). Toxic effect of five plant extract against larger grain borer, Prostephanus truncates. Afr. J. Agricul. Res., 5 (24):3369–3378.
[48] Singh, D.K. (2012). Pesticides and Environment. Pestic. Chem. Toxicol. 1:114–122.
[49] Weinzierl, R.A. (2000). Botanical insecticides, soaps, and oils In: Biological and Biotechnological Control of Insect Pests. Ed. J. E. Rechcigl, N. A. Rechcigl. 101–121.
[50] El-Wakeil, N.E. (2013). Botanical Pesticides and Their Mode of Action. Gesunde Pflanzen 65:125-149.

[51] Eldridge, J.C.; Wetzel, L.T.; Stevens, J.T. and Simpkins, J.W. (1999). The mammary tumor response in triazine-treated female rats: A threshold-mediated interaction with strain and species-specific reproductive senescence. Steriods. 64:672-678.

[52] Gómez, A.S.; Calderón-Segura, M.E. and Villalobos Pietrini, R. (2000). Biomonitoring of pesticides by plant metabolism: an assay base on the induction of sister-chromatid exchanges in human lymphocyte cultures by promutagen activation of Vicia faba. In: Biomonitors and biomarkers as indicators of environmental change. Plenum Press, New York. 2:439-455.

[53] Ergene, S.; Cavas, T.; Celik, A.; Koleli, N.; Kaya, F. and Karahan, A. (2007). Monitoring of nuclear abnormalities in peripheral erythrocytes of three fish species from the Goksu Delta (Turkey): Genotoxic in relation to water pollution. Ecotoxicology, 16:385-391.

[54] Undeger, U. and Basaran, N. (2002). Assessment of DNA damage in workers occupationally exposed to pesticide mixtures by alkaline comet assay. Archives of Toxicology 76:430-436.

[55] Costa, C.; Silva, S.; Coelho, P.; Roma-Torres, J.; Teixeira, J.P. and Mayan, O. (2007). Micronucleus analysis in a Portuguese population exposed Environ Sci. Pollut. Res. to pesticides: preliminary survey. Int J Hyg Environ Health. 210(3-4):415–418.

[56] Yadav, I.C. and Devi, N.L. (2017). Pesticides classification and its impact on Human and environment. Environ.sci & engg. Toxicology. 6:140-158.

[57] Megha, M.; Akashe, A.V.N. and Uday, V.P. (2018). Classification of pesticides: a review. Int. J. Res. Ayurveda Pharm. 9(4):144-150.

[58] WHO, World health organization. (2018). Pesticide residues in food. Available at. https://www.who.int/news-room/fact-sheets/detail/pesticide-residues-in-food

[59] FAO.(2011) Food and Agriculture Organization of the United Nations. Available at: http://faostat.fao.org/site/339/default.aspx.

[60] Gregory, E.W. (2015). Vegetable History, Nomenclature, and Classification. Vegetable Production and Practices (G.E. Welbaum).

[61] Ibeawuchi, I.I; Okoli, N.A; Alagba,R.A; Ofor,M.O; Emma-Okafor, L.C; Peter-Onoh, C.A and Obiefuna, J.C. (2015). Fruit and Vegetable Crop Production in Nigeria: The Gains, Challenges and the Way Forward. Journal of Biology, Agriculture and Healthcare. 5:2.

[62] Muyesaier, T.; Hauda, R.; Li, W. and Dung, T.P. (2021). Agriculture Development, Pesticide Application and Its Impact on the Environment. International Journal of Environmental Research and Public Health 18(3):1112.

[63] Zhang, W.; Jiang, F. and Ou, J. (2011). Global pesticide consumption and pollution: With China as a focus. Proc. Int. Acad. Ecol. Environ. Sci. 1:125.

[64] Zahid, A.; Muhammad, S.; Ali, S.; Mujeeb, R.; Soomro, A.; Zaib, J.; Nazia, R.; Zaira P. T. and Farheen, S. (2016). Farmers' Perceptions about Effects of Pesticides Use in Vegetables in Taluka Usta Muhammad of Jaffarabad district, Balochistan. Journal of Natural Sciences Research.

[65] Bajwa, U. and Sandhu, K.S. (2014). Effect of handling and processing on pesticide residues in food- a review. J Food Sci Technol 51(2):201-220.

[66] Ajmer, S.G.; Ashish, S.; Pradeep, K. and Jagdeep, S.D. (2017). Pesticide Residues in Food Grains, Vegetables and Fruits: A Hazard to Human Health. J Med Chem Toxicol. 2:1.

[67] Aktar, W.; Sengupta, D. and Chowdhury, A. (2009). Impact of pesticides use in agriculture: Their benefits and hazards. Interdiscip. Toxicol. 2:1–12.

[68] Maroni, M.; Fanetti, A.C. and Metruccio, F. (2006). "Risk assessment and management of occupational exposure to pesticides in agriculture''. La Medicina del Lavoro. 97:430-437

[69] Cooper, J. and Dobson, H. (2007). "The benefits of pesticides to mankind and the environment''. Crop Protection, 26:1337-1348

[70] Ridsdill-Smith, T. and Pavri, C. (2017). "Single Spring Spray Protects Pastures''. Available online: https://www.agric.wa.gov.au/pastures/spray-topping-declared-plants.

[71] Miraglia, M.; Marvin, H.; Kleter, G.; Battilani, P.; Brera, C.; Coni, E.; Cubadda, F.; Croci, L.; De Santis, B.; and Dekkers, S. (2009). "Climate change and food safety: An emerging issue with special focus on Europe''. Food Chem. Toxicol. 47:1009–1021.

[72] Mingo, V.; Lötters, S. and Wagner, N. (2017). "The impact of land use intensity and associated pesticide applications on fitness and enzymatic activity in reptiles—A field study''. Sci. Total Environ. 590:114– 124.

[73] Kim, Y.S.; Park, K.H.; Chun, H.S.; Choi, C. and Bahk, G.J. (2015). "Correlations between climatic conditions and foodborne disease''. Food Res.Int. 68: 24–30.

[74] Gouin, T.; Shoeib, M. and Harner, T. (2008). "Atmospheric concentrations of current-use pesticides across south-central Ontario using monthly-resolved passive air samplers''. Atmos. Environ. 42:8096–8104.

[75] Singh, D.K. (2012). ''Pesticides and Environment''. Pestic. Chem. Toxicol. 1:114–122.

[76] Fang, Y.; Nie, Z.; Die, Q.; Tian, Y.; Liu, F.; He, J. and Huang, Q. (2017). "Organochlorine pesticides in soil, air, and vegetation at and around a contaminated site in southwestern China: Concentration, transmission, and risk evaluation''. Chemosphere. 178:340–349.

[77] Shakeri, A. and Mehrabi, B. (2015). "Potentially toxic elements and persistent organic pollutants in water and fish at Shahid Rajaei Dam, north of Iran''. Int. J. Environ. Sci. Technol. 12:2201–2212.

[78] Barron, M.; Ashurova, Z.J.; Kukaniev, M.A.; Avloev, H.K.; Khaidarov, K.K.; Jamshedov, J.N.; Rahmatullova, O.S.; Atolikshoeva, S.S.; Mamadshova, S.S. and Manzenyuk, O. (2017). ''Residues of organochlorine pesticides in surface

soil and raw foods from rural areas of the Republic of Tajikistan''. Environ. Pollut. 224:494–502.
[79] Zhang, F.; He, J.; Yao, Y.; Hou, D.; Jiang, C.; Zhang, X.; Di, C. and Otgonbayar, K. (2013). "Spatial and seasonal variations of pesticide contamination in agricultural soils and crops sample from an intensive horticulture area of Hohhot, North-West China''. Environ. Monit. 185:6893–6908.
[80] Wu, L.; Chang, H. and Ma, X. A. (2017). "Modified method for pesticide transport and fate in subsurface environment of a winter wheat field of Yangling, China''. Sci. Total Environ. 609:385–395.
[81] Yadav, I.C.; Devi, N.L.; Syed, J.H.; Cheng, Z.; Li, J.; Zhang, G. and Jones, K.C. (2015). ''Current status of persistent organic pesticides residues in air, water, and soil, and their possible effect on neighboring countries: A comprehensive review of India''. Sci. Total Environ. 511:123–137.
[82] Damalas, C.A. Eleftherohorinos, I.G. (2011). "Pesticide Exposure, Safety Issues, and Risk Assessment Indicators''. International Journal of Environmental Research and Public Health, 8:1402-1419.
[83] Wang, D.; Singhasemanon, N. and Goh, K.S. (2017). "A review of diazinon use, contamination in surface waters, and regulatory actions in California across water years 1992–2014''. Environ. Monit. 189:310.
[84] Andreu, V. and Picó, Y. (2004). "Determination of pesticides and their degradation products in soil: Critical review and comparison of methods''. TrAC Trends Anal. Chem. 23:772–789.
[85] Strassemeyer, J.; Daehmlow, D.; Dominic, A.; Lorenz, S. and Golla, B. (2017). "SYNOPS-WEB, an online tool for environmental risk assessment to evaluate pesticide strategies on field level''. Crop Prot. 97:28–44.
[86] Ansara-Ross, T.; Wepener, V.; Brink, P.V.D. and Ross, M. (2012). ''Pesticides in South African fresh waters''. Afr. J. Aquat. Sci. 37:1–16.
[87] Adams, R.M.; McAdams, B.C.; Arnold, W.A. and Chin, Y.-P. (2016). "Transformation of chlorpyrifos and chlorpyrifos-methyl in prairie pothole pore waters''. Environ. Sci. Process. Impacts, 18:1406–1416.
[88] Mazlan, N.; Ahmed, M.; Muharam, F.M. and Alam, M.A. (2017). "Status of persistent organic pesticide residues in water and food and their effects on environment and farmers: A comprehensive review in Nigeria''. Semin.-Cienc. Agrar. 38:2221–2236.
[89] Kurwadkar, S. (2017). "Groundwater Pollution and Vulnerability Assessment''. Water Environ. Res. 89: 1561–1577.
[90] Lai, W.Y. (2017). "Pesticide use and health outcomes: Evidence from agricultural water pollution in China''. J. Environ. Econ. Manag. 86:93–120.
[91] Guo, H. and Wang, Y. (2004). "Specific vulnerability assessment using the MLPI model in Datong city, Shanxi province, China''. Environ. Earth Sci. 45:401–407.
[92] Aravinna, P.; Priyantha, N.; Pitawala, A. and Yatigammana, S.K. (2018). "Use pattern of pesticides and their predicted mobility into shallow groundwater and surface water bodies of paddy lands in Mahaweli river basin in Sri Lanka''. J. Environ. Sci. Health Part B-Pestic. Food Contam. Agric. Wastes, 53:95.
[93] Liu, Y.; Mo, R.; Tang, F.; Fu, Y. and Guo, Y. (2015). "Influence of different formulations on chlorpyrifos behavior and risk assessment in bamboo forest of China''. Environ. Sci. Pollut. Res. 22:20245–20254.
[94] Langenbach, T.; Mano, D.; Campos, M.M.; Cunha, A.L. and De Campos, T.M. (2017). "Pesticide dispersion by spraying under tropical conditions''. J. Environ. Sci. Health Part B, 52:843–849.
[95] Lee, S.; McLaughlin, R.; Harnly, M.; Gunier, R.B. and Kreutzer, R. (2002). "Community exposures to airborne agricultural pesticides in California: Ranking of inhalation risks''. Environ. Health Perspect. 110:1175–1184.
[96] Đuriši´c-Mladenovi´c, N.; Škrbi´c, B. and Cvejanov, J. (2010). "Organochlorine Pesticides in Soil and Sediment from an Urban Zone of Novi Sad, Serbia''. In Survival and Sustainability: Environmental Concerns in the 21st Century; Springer: Berlin/Heidelberg, German, p.1469–1481.
[97] De Jong, F.M.; de Snoo, G.R. and Van de Zande, J.C. (2008). "Estimated nationwide effects of pesticide spray drift on terrestrial habitats in the Netherlands''. J. Environ. Manag. 86:721–730.
[98] Yera, A.M.B.; Nascimento, M.M.; da Rocha, G.O.; de andrade, J.B. and Vasconcellos, P.C. (2020). "Occurrence of Pesticides Associated to Atmospheric Aerosols: Hazard and Cancer Risk Assessments''. J. Braz. Chem. Soc. 31:1317–1326
[99] Benka-Coker, W.; Hoskovec, L.; Severson, R.; Balmes, J.; Wilson, A. and Magzamen, S. (2020). ''The joint effect of ambient air pollution and agricultural pesticide exposures on lung function among children with asthma''. Environ. Res. 190:109903.
[100] Doan, N.H.; Duong, H.T.; Trinh, H.T.; Tanaka, Y. and Kadokami, K. (2021). "Comprehensive study of insecticides in atmospheric particulatematter in Hanoi, Vietnam: Occurrences and human risk assessment''. Chemosphere, 262:128028.
[101] Pan, D.; He, M. and Kong, F. (2020). "Risk attitude, risk perception, and farmers' pesticide application behavior in China: A moderation and mediation model''. J. Clean. Prod. 276:124-241.
[102] Sultana, J.; Syed, J.H.; Mahmood, A.; Ali, U.; Rehman, M.Y.A.; Malik, R.N.; Li, J. and Zhang, G. (2014). "Investigation of organochlorine pesticides from the Indus Basin, Pakistan: Sources, air–soil exchange fluxes and risk assessment''. Sci. Total Environ. 497:113–122.
[103] Carvalho, F.P. (2017). "Pesticides, environment, and food safety''. Food Energy Secur, 6:48–60.
[104] Zhang, Q.; Xia, Z.; Wu, M.; Wang, L. and Yang, H. (2017). "Human health risk assessment of DDTs and HCHs through dietary exposure in Nanjing, China''. Chemosphere.

177:211–216.
[105] Wendie L.C.; Claude, B.; and Guy, M. (2011). “Exposure of several Belgian consumer groups to pesticide residues through fresh fruit and vegetable consumption”. Food Control, 22:508–516.
[106] Zorka K.M.S. and Marijan A. (2012). “Risk assessment of the intake of pesticides in Croatian diet’’. Food Control, 23:59–65.
[107] Wanwimolruk, S.; Phopin, K.; Boonpangrak, S. and Prachayasittikul, V. (2016). “Food safety in Thailand 4: Comparison of pesticide residues found in three commonly consumed vegetables purchased from local markets and supermarkets in Thailand’’. PeerJ, 4:2432.
[108] Bolognesi, C. and Merlo, F.D. (2011). “Pesticides: human health effects”. In: Nriagu JO (ed): Encyclopedia of environmental health Burlington: Elsevier. 438-453.
[109] Peterson, D.E.; Shoup, D.E.; Thompson, C.R. and Olson, B.L. (2013). “Herbicide mode of action, cooperative extension service”. Kansas: Kansas State Univ.
[110] Sathiakumar, N.; MacLennan, P.A.; Mandel, J. and Delzell, E. (2011) “A review of epidemiologic studies of triazine herbicides and cancer”. Crit Rev Toxicol. 41:1-34.
[111] Volodymyr, I.L.; Tetiana, M.M.; Viktor, V.H.; Janet, M.S. And Kenneth, B.S. (2018). “Pesticide toxicity: a mechanistic approach’’. EXCLI Journal, 17:1101-1136.
[112] Giddings, J.M.; Anderson, T.A.; Hall, L.W.; Kendall, R.J.; Richards, R.P. and Solomon, K.R. (2005). “A probabilistic aquatic ecological risk assessment of atrazine in North American surface waters”. Pensacola, FL: SETAC Press.
[113] Jegerschöld, C.; Arellano, J.B.; Schröder, W.P.; Van Kan, P.J.; Barón, M. and Styring, S. (1995). “Copper (II) inhibition of electron transfer through photosystem II studied by EPR spectroscopy”. Biochemistry. 34:12747-12754.
[114] Küpper, H.; Küpper, F. and Spiller, M. (1996). “Environmental relevance of heavy metal-substituted chlorophylls using the example of water plants”. J Exp Bot. 47:259-266.
[115] Burda, K.; Kruk, J.; Schmid, H.G. and Strzalka, K. (2003). “Inhibition of oxygen evolution in photosystem II by Cu(II) ions is associated with oxidation of cytochrome b559”. Biochem J. 371: p.591-601.
[116] Balba, H. (2007). “Review of strobilurin fungicide chemicals’’. J Environ Sci Health. 42:441-451.
[117] Casida, J.E. and Durkin, K.A. (2017). “Pesticide chemical research in toxicology: lessons from nature’’. Chem Res Toxicol. 30:94-104.
[118] Jablonkai, I. (2011). “Molecular mechanism of function of herbicides”. In: Hasaneen MNAE-G (ed): Herbicides – mechanisms and mode of action. Croatia: InTech.3-24.
[119] Rizzati, V.; Briand, O.; Guillou, H. and Gamet-Payrastre, L. (2016). “Effects of pesticide mixtures in human and animal models: An update of the recent literature”. Chem Biol Interact. 254:231-246.
[120] Galloway, T. and Handy, R. (2003). “Immunotoxicity of organophosphorous pesticides”. Ecotoxicology. 12:345-363.
[121] González, M.; Soloneski, S.; Reigosa, M.A. and Larramendy, M.L. (2003). “Effect of dithiocarbamate pesticide zineb and its commercial formulation, azzurro. IV. DNA damage and repair kinetics assessed by single cell gel electrophoresis (SCGE) assay on Chinese hamster ovary (CHO) cells”. Mutat Res.534:145-154.
[122] Soloneski, S.; Reigosa, M.A. and Larramendy, M.L. (2002). “Effect of dithiocarbamate pesticide zineb and its commercial formulation, azzurro II micronucleus induction in immunophenotyped human lymphocytes”. Environ Mol Mutagen. 40:57-62.
[123] Calviello, G.; Piccioni, E.; Boninsegna, A.; Tedesco, B.; Maggiano, N. and Serini, S. (2006). “DNA damage and apoptosis induction by the pesticide Mancozeb in rat cells: Involvement of the oxidative mechanism”. Toxicol Appl Pharmacol. 211:87-96.
[124] Chelme-Ayala, P.; El-Din, M.G. and Smith, D.W. (2005). “Guest RK. Pesticides and herbicides”. Water Environ Res. 77:2021- 2129.
[125] Eldridge, J.C.; Wetzel, L.T.; Stevens, J.T. and Simpkins, J.W. (1999). “The mammary tumor response in triazine-treated female rats: A threshold-mediated interaction with strain and species-specific reproductive senescence”. Steriods. 64:672-678.
[126] Oruc, H.H. (2010). “Fungicides and their effects on animals”. In: Carisse O (ed): Fungicides Rijeka: InTech. 349-362.
[127] Cox, C. (1997). “Chlorothalonil, Fungicide Factsheet”. J Pestic Reform. 17:14-20.
[128] Franco, R.; Li, S.; Rodriguez-Rocha, H.; Burns, M. and Panayiotidis, M.I. (2010). “Molecular mechanisms of pesticide induced neurotoxicity: Relevance to Parkinson’s disease”. Chem Biol Interact. 188:289- 300.
[129] Abdollahi, M.; Ranjbar, A.; Shadnia, S.; Nikfar, S. and Rezaie, A. (2004). “Pesticides and oxidative stress: a review”. Med Sci Monit. 10:141-147.
[130] Banerjee, B.D.; Seth, V.; Bhattacharya, A.; Pasha, S.T. and Chakravorty, A.S. (1999). ‘’Biochemical effects of some pesticides on lipid peroxidation and free-radical scavenger’’. Toxicol. Lett., 107:33-47.
[131] Lushchak, V.I. (2016). “Contaminant-induced oxidative stress in fish: a mechanistic approach”. Fish Physiol Biochem. 42:711-747.
[132] Lushchak, V.I. (2012). “Glutathione homeostasis and functions: potential targets for medical interventions”. J Amino Acids.736 - 837.
[133] Atamaniuk, T.M.; Kubrak, O.I.; Storey, K.B. and Lushchak, V.I. (2013). “Oxidative stress as a mechanism for toxicity of 2,4-dichlorophenoxyacetic acid (2,4-D): studies with goldfish gills”. Ecotoxicology. 22:1498-1508.
[134] Kubrak, O.I.; Atamaniuk, T.M. Storey, K.B. and Lushchak, V.I. (2013). “Goldfish can recover after short-term exposure to 2,4-dichlorophenoxyacetate: Use of blood parameters as vital biomarkers”. Comp Biochem Physiol C

Toxicol Pharmacol. 157:259-265.
[135] Campos, E.V.R.; De Oliveira, J.L.; Pascoli, M.; De Lima, R.; Fraceto, L.F. (2016). "Neem oil and crop protection: From now to the future''. Front Plant Sci., 7:1494.
[136] Mahendra, P.; Biniyam, M.; Manyazewal, A. and Selamawit Mulu, P.K.S. (2016). "Public Health significance of Pesticides in Foods of Animal origin". Beverage and Food World, Vol. 43:5.
[137] Maroni, M.; Fanetti, A.C. and Metruccio, F. (2006). "Risk assessment and management of occupational exposure to pesticides in agriculture''. La Medicina del Lavoro. 97:430-437
[138] Soares, W.L. and Porto, M.F.D. (2009). "Estimating the social cost of pesticide use: An assessment from acute poisoning in Brazil''. Ecological Economics. 68:2721-2728.
[139] Dawson, A.H.; Eddleston, M.; Senarathna, L.; Mohamed, F. and Gawarammana, I. (2010). "Acute human lethal toxicity of agricultural pesticides: A prospective cohort study". PLoS Medicine 7(1):357.
[140] Lee, S.J.; Mehler, L.; Beckman, J.; Diebolt-Brown, B.; Prado, J.; Lackovic, M.; Waltz, J.; Mulay P.; Schwartz, A.; Mitchell, Y.; Moraga-McHaley, S.; Gergely, R. and Calvert, G.M. (2011). "Acute pesticide illnesses associated with off target pesticide drift from agricultural applications: 11 States, 1998-2006''. Environmental Health Perspectives, 119:11–62.
[141] Singh, B. and Mandal, K. (2013). "Environmental impact of pesticides belonging to newer chemistry. In: Dhawan, A.K., Singh, B., Brar-Bhullar, M. and Arora, R. (Eds.)''. Integrated pest management. Scientific Publishers, Jodhpur, India. 152–190.
[142] Zhang, C-Z.; Tian Z-H.; He D-J.; Liu X-J. (2010). "Degredation of Chlorpyrifos and Fipronil in Rice from Farm to Fork and Risk Assessment''. Science Direct, 9(5):754–763.
[143] Fothergill, M. and Abdelghani, A. (2013). "A review of pesticide residue levels and their related health exposure risks''. WIT Transactions on Ecology and the Environment. 170.
[144] National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture and Cooperatives (NBACFS) (2014). Published in the Royal Gazette, Announcement and General Publication, Volume 131:special section 32 (NGO).