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Causes and management of pesticides contamination in agriculture: A review

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ABSTRACT

The development and application of pesticides such as insecticides, fungicides, herbicides/weedicides, rodenticides, nematicides and other registered and unregistered materials for pests' control during crop production, have come with their accompanied risks of contamination in the environment. Failure by applicators in following safety protocols associated with pesticide application, handling, storage and disposal leads to contamination and poisoning of water sources, nearby food and feed materials, beneficial animals, applicators themselves and other farm workers. This review considered dangers associated with pesticides contaminations and poisonings, events that lead to pesticides contaminations, common symptoms and disorders of pesticides poisonings, types and classes of pesticides, groups that are vulnerable to pesticides contaminations and poisonings. It also focused on some best alternative measure to employ in order to curb hazards associated with pesticides use. To achieve this, there is a need for proper implementation, strengthen of government's pesticides regulatory bodies and enforcement of related regulations. Stakeholder fora and intensification of education on pesticides use, handling, storage and disposal for dealers, distributors and the users are required. Also, the production and release of detoxifying agents into industrial drainage systems, water sources that can potentially be contaminated as well as into farmlands and the environment, is necessary to ensure effective management and reductions in the incidences of pesticides contaminations. It is thus, necessary to enforce the much needed precautions and alternative measures required to mitigate global and local cases of pesticide hazards.

Keywords: *Contaminations, Crop production, Environment, Pesticides, Precautionary measures*

INTRODUCTION

Pesticide is a broader term that covers all kinds of pests' control agents such as fungicide, weedicide, herbicide, termiticide, molluscicides, nematicide, rodenticide, bactericide, avicide, disinfectant and repellents (Carolyn *et al*., 2013). However, herbicides are the most common and widely used (i.e., about 80% of all pesticide usage) (Holm and Johnson, 2009; Sebiomo *et al*., 2011). Most pesticides are hazardous with a few of them being extremely harmful. The latter cause unmeasurable danger to human health and the environment (FAO and WHO, 2019). In terms of usage, some of the world's largest pesticide users countries in the world are the EU, Brazil, USA, and China, each using 827 million, 831 million, 1.2 billion, and 3.9 billion pounds of pesticides in 2016, respectively (FAO, 2016).

Pesticides are primarily used at various phases of the food and feed industries; production, transport, processing, distribution, storage and in farm animals to control external parasites (Yamada, 2017). Consequently, residues emanating from these exposures in food materials are

reported to be almost 10,000 – 100,000,000,000 times above those resulting from contaminated air or water for domestic use (Tomer *et al*., 2015). There is an overwhelming spread of ecosystems contaminations by pesticides across the globe (Ferrario *et al.,* 2017; Silva *et al.*, 2019). These result in adverse effects on human health such as rashes, reproductive problems, neurotoxicity and breathing difficulties (Kumar and Kumar, 2019). They may also lead to severe and/or chronic infections such as cancer (Bento *et al*., 2017; Kumar and Kumar, 2019; Shang *et al*., 2019).

Pesticides contain active compounds which have significantly contributed to agriculture. For insecticides, the most extensive used around the world are Neonicotinoids. They are used to treat seeds or sprayed on foliage of a wide range of crops because of their systemic mode of actions (Pisa *et al.,* 2015). According to Zhang (2018), the global use of pesticides is estimated to rise up to about 3.5 MT, by 2020. Meanwhile, most of them are very persistent and nondegradable, and as such, reasonable quantum of residues is detected in water and soil environments, accounting for high environmental contaminations (Pisa *et al*., 2015; FAO and WHO, 2019). This review considered dangers associated with pesticides contaminations and poisonings, events that lead to pesticides contaminations, common symptoms and disorders of pesticides poisonings, types and classes of pesticides, groups that are vulnerable to pesticides contaminations and poisonings. It also focused on some best alternative measure to employ in order to curb hazards associated with pesticides use. The aim of this review was to determine the causes and management of pesticides contamination in agriculture.

Types of pesticides

Botitsi *et al.* (2017) reported that pesticides are categorized on the basis of their chemical structures, toxicity, mechanisms of action and active compounds it contains. The inorganics and organics are the two main groups of pesticides. The organic group of pesticides contain carbon as their main and primary ingredient and may be natural in origin (i.e., obtained from materials that exist in nature) or artificially made from synthetic pesticides (i.e., from chemicals of organic origins) (Biondi *et al*., 2012). The inorganic pesticides are obtained from chemical and mineral compounds occurring as non-living natural deposits, mostly elements and minerals of chemical origins such as boron, mercury, copper, sulphur, zinc, thallium, phosphorus and fluorine (Patinha *et al*., 2018). Examples of pesticides categorization based on their toxicity to the dermal tissue of rat, the accepted toxicological principle is shown in Table 1 while those that can be classified on the basis of the type of pests they control is shown in Table 2. Categorization according to active ingredients compositions and chemical nature is shown Table 3.

TABLE 1. **Pesticide classes based on toxicology**

Pesticide class	**Degree of toxicity**	**LD_{50} for test rat: Body weight (mg/kg)**	
		Oral	**Dermal**
Ia	Extremely hazardous	< 5	< 50
Ib	Highly hazardous	5 – 50	50 – 200
II	Moderately hazardous	50 – 2000	200 – 2000
III	Slightly hazardous	Over 2000	Over 2000
U	Unlikely to cause acute Hazard	Over 5000 or more	

(WHO, 2010).

TABLE 2. **Pesticides types based on the types of pests controlled**

Pesticide	Target pest(s)
Weedicide	Specific annual, biennial, perennial weeds
Herbicide	General broad and narrow leaf weeds, trees, shrubs
Termiticide	Termites
Molluscicide	Molluscs
Nematicide	Nematodes
Rodenticide	Rodents e.g. Rats, mice, monkey, squirrel etc
Piscicide	Fishes
Fungicide	Fungi
Bactericide	Bacteria
Avicide	Birds
Disinfectant and repellents	Virus, mosquitoes, flies, etc

(Carolyn *et al*., 2013; Pandya, 2018)

TABLE 3. **Some commonly used pesticides and their toxicity class, according to WHO classification**

Trade name	Active compound (s)	Toxicity class
Lambda	Lambda cyhalothrin	II
Sunphosate, Sarosate, Vinash, Glygot, Nwuranwura, Touchdown, D-lion	Glyphosate	III
Utrazin, Atrazine	Atrazine	III
Agristomp	Pendimethalin	II
Kombat, Kadmaneb, Kilsct	Lambda cyhalothrin	II
Ceres, Butachcor	Butachlor	III
Controller	Lambda cyhalothrin + cypermethrin	II

II means toxic or moderately hazardous; III means slightly hazardous (WHO, 2010 Classification based on toxicity; Imoro *et al*., 2019).

Causes of pesticides contaminations and poisonings in Agriculture

There are growing concerns about the indiscriminate use of agrochemicals without adhering to safety protocols (Okoffo *et al.,* 2016). Pesticides contaminations are as a result of a series of actions such as the transportation of pesticides, spray drifts, pesticides particles on leaves after spraying, spillage on soils, grounds, floors, wooden and plastic materials, poor disposal of empty containers of pesticides, storage, carrying by surface runoff etc. (FAO and WHO, 2019). Some evidence suggests that poor and relaxed regulations, assessments and absence of enforcement strategies for pesticide applications, are the reasons for the increasing dangers of the negative health impacts and environmental pollution due to pesticides, especially in the least developed nations (Bornman *et al*., 2017). Most farmers in these countries do not have formal education and as such, some do not adhere to the necessary precautionary measures for safe application of pesticides. Consequently, this exposes the farmers, environment, crops, beneficial organisms and water sources to the highest potential risks associated with pesticides (Imoro *et al*., 2019).

The misapplication and indiscriminate use of pesticides in past times has contributed

to contaminations in the surroundings through aggregation of residues, spills, and drips in the soil, air, food, water resources and feed (Rahaman *et al*., 2018). Pesticides contaminations also arise from handling and application without wearing recommended personal protection equipment that are stated by the manufacturers on the labels. Also, pesticides use and safety sensitization programmes are limited and where farmers are aware, the costs of personal protective equipment and suitability of their use makes them prohibitive. (FAO and WHO, 2020).

Pesticides contaminations and implications on human and animals

The increasing effects of inappropriate use of pesticides has attracted the attentions of researchers, policy- makers, and the general public globally (Okoffo *et al*., 2016). According to Zhang (2018), the application of pesticides and their related contaminations in our daily lives has resulted in several kinds of disorders in human and animals, and also, caused damages to humans' intelligence and fecundity. The various classes of pesticide categorized by the World Health Organization (WHO) have the potentials of causing sharp toxicity among animals particularly mammals, when administered orally. In contrast, they pose less risk of toxicity when they come into contact with the skin or inhaled (Ndayambaje *et al.*, 2019). The degrees of pesticides exposure among people working in farms, are higher than the rest of the human population. Research shows that exposure to pesticides is characterized by birth defects, leukemia, and infant's mortality (UNICEF, 2018). Children are highly exposed to pesticides and their related poisonings due to inappropriate applications, poor storage at homes and spillages on grounds, floors, fruits and vegetables (UNICEF, 2018). A report by WHO (2019) estimates that about 3,000,000 poisonings and 220,000 pesticides associated deaths occur annually, most particularly in the least developed regions of the world (Kaur *et al*., 2019). Pesticide contamination and poisoning in children can lead to chronic health issues like cancer, defects in new-born babies, still-births, disorganized endocrine systems and retardation of neurons developments in children's (UNICEF, 2018). Luz *et al*. (2018) reported that Pyraclostrobin induces mitochondrial malfunctioning by reducing the mitochondrial membrane and respiration connected to adenosine-5-triphosphate (ATP); this leads to the aggregation of triglyceride. Recent research found that, the agent diquat, which is used in place of rotenine and paraquat herbicide cause malfunction of the mitochondria and sequential cell death (Choi *et al*., 2018).

Further, pesticides containing i*midacloprid* cause toxicity in birds when consumed orally (Ronald and National, 2011; Ndayambaje *et al*., 2019). Inappropriate disposal of pesticides negatively affects beneficial and non-target living organisms such as the fishes, butterflies, honey-bees, soil microorganisms and birds (Buah-Kwofie *et al*., 2018). The most persistent organochlorine pesticide, Dichloro Diphenyl Trichloroethane (DDT), which has adverse effects on human health and persistence in the environment was found in blood, umbilical cord, breast milk, placentas, fetuses and the amniotic fluid in the past, thus leading to the discontinuation of its use for pest control globally (Botwe *et al*., 2012; Brühl and Zaller, 2019). Chemical compounds in some pesticides are soluble in fats, and therefore have the ability to penetrate the skin, respiratory tract, mucous membrane of the mouth, gastrointestinal walls, and the lubricating membrane of the eyeball, when exposed to them (Sharma *et al*., 2020). The negative effects posed on the diversity, activities and physiology of beneficial terrestrial organisms and several kinds of aquatic lives have been reported in many studies (Brühl and Zaller, 2019). Sánchez-Bayo and Wyckhuys (2019) reported that, pollutions caused by chemical substances, including

pesticides, have been identified as the second most powerful force responsible for global declines in populations of insect species.

Pesticides have different mechanisms of actions in pests and other living organisms and these include interfering with the synthesis of proteins, cell divisions, respiration, amino acid, nervous system and deoxyribonucleic acid (DNA) injury (Zikankuba *et al*., 2019). Although least developed countries use about 25% of the total volume of pesticides produced globally, these countries rather record about 99% of pesticides associated deaths (WHO, 2008). Pesticides interference with oxidative processes in human body causes oxidative imbalances which results in the development of health problems such as neuro-degeneration, respiratory disorders, carcinogenesis, reproductive abnormalities and endocrine malfunctionings (Kaur, *et al*., 2019). Effects of pesticides on some organisms are shown in Table 4.

TABLE 4. **Negative effects of pesticides on beneficial organisms**

Organism/insect	**Benefits**	**Pesticides effect**	**Reference**
Mammals, Hedgehog	Pollination and biocontrol of insect pests	Diminishing of preys and dehabitation due to indirect pesticide effects on adjacent environments and decrease in population	Mathews *et al*. (2018)
Lady bird beetle	Biocontrol agent for aphids	Negatively affected by non-selective pesticides	Di Vitantonio *et al*. (2018)
Reptiles, amphibians	Predation, and also serve as food for man and other higher mammals	Exposure to pesticides in their food, habitats, soil, water, directly from spray drifts play harmful effects on their growth and reproductions.	9 Ockleford *et al*. (2018)
Flying insects	Pollination	Drastic decline in population due to exposure to pesticides	Hallmann *et al.* (2017)
Butterflies	Pollination and good indicators of ecological health	Killing and dehabitation by neonicotinoid pesticide application	Braak *et al*. (2018)
Ground beetles	Biocontrol agent for pests of cereals.	Neonicotinoid use affect their nutrition and population growth	Labruyere *et al*. (2006)
Hoverflies	Pollination, compost decomposition, prey on aphids	Thiamethoxam exposure causes high mortality among them	Basley *et al.* (2018)
Bees	Efficient pollination	Synthetic and botanicals cause acute toxicity to be on field during foraging	Ndakidemi *et al*. (2016)

Earthworm	Decomposition and soil aeration	Decrease in population and normal growth weight	Science Daily, 2014; Chen *et al*. (2018)
Damselflies	Predatory actions	Toxicity and death by exposure to neonicotinoid thiacloprid, slow down growth	Barmentlo *et al*. (2019)
Dragonflies	Predation effect on aquatic insect pests	Application of fipronil pesticides in rice field greatly decreased the population of these flies	Nakanishi *et al*. (2018)
Aquatic lives	Food; fishes, crab, shrimps, etc.	neonicotinoid contamination in irrigation channels, streams, rivers has led to the decline of many aquatic invertebrates populations.	Sánchez-Bayo *et al*. (2016)

Pesticides contaminations and implications on food and food products

Pesticide residues have been detected in honey and in fruits, cereals and vegetables. The degree of these residues varies due to practices by processors and growers (Heard *et al*., 2017). Most pesticides are detected in blood, milk and tissues containing fats, due to accumulation of the residues in the food chain (Buah-Kwofie *et al*., 2018). A 2016 research by Pesticide Action Network (2017) in Thailand, reported the presence of 35-100% deposits of residues of toxic pesticides, banned from use in the country, in food commodities such as vegetables and fruits sold at local and super markets. The high rate of pesticides usage leaves deposits of residues in crop produce, which eventually find its way into the food system posing risks to man and animals (Sharma *et al*., 2017). In Ghana, vegetables to EU were rejected because of pesticides (Fianko *et al*., 2011; Bempah *et al*., 2011; Maden *et al*., 2014).

Pesticides contaminations and implications on the environment

The organochlorine group of pesticides like DDT, dieldrin, aldrin, endosulfan, hexachlorocyclohexane and hexachlorobenzene are highly nondegradable and persist in our environment over a long period of time after use (Jayaraj *et al*., 2016) that is why they are banned from being sold on the market in most countries. There are cases of pesticide related contaminations of soils, underground and surface water (FAO and WHO, 2019). Most pesticide pollution occur in soils and water environments (Sharma *et al.*, 2017). Residues of pesticides of organic origins remain in the surroundings and can be detrimental to plants, water sources and soil environments (Sharma *et al*., 2018; Sharma *et al*., 2019). Glyphosate has been identified as the main active constituent of most pesticides, posing serious risk to the native flora in addition to the negative effects on grasses and herbs (Jayaraj *et al*., 2016). Some pesticide ingredients including atrazine and diuron have been detected in several water

sources at higher concentrations in Australia (Allinson *et al*., 2017). Residual deposits of 10 insecticides, 11 fungicides, of 21 herbicides, one growth hormone, 21 herbicides were found in some surface water sources at Brazil (Albuquerque *et al.*, 2016). A large number of the populace in Ghana cannot read and understand herbicide label. This has resulted in the contamination of streams, rivers and ground water which is an important natural resource (Baran *et al*., 2007). These contaminations do not pose danger to only the non-target organisms and the environment but exposes human beings to many health implications.

Pathways for pesticides entry into the body

The presence of pesticides in humans and animals can occur by ocular (eyes), dermal (skin), inhalation (lungs and the nose) and oral (mouth) entries (Figure 2). Most occupational related pesticide contaminations, poisonings and hazards occur through inhalations and dermal entry as a result of application flashes, drifts from sprays, mixing, loading and contact with sprayed materials, surfaces or crops (Figure 2). Ingestion by mouth and absorption by the skin occurs accidentally through treated surfaces, sprayed fruits and food materials or by will as a means of committing suicides (FAO and WHO, 2020).

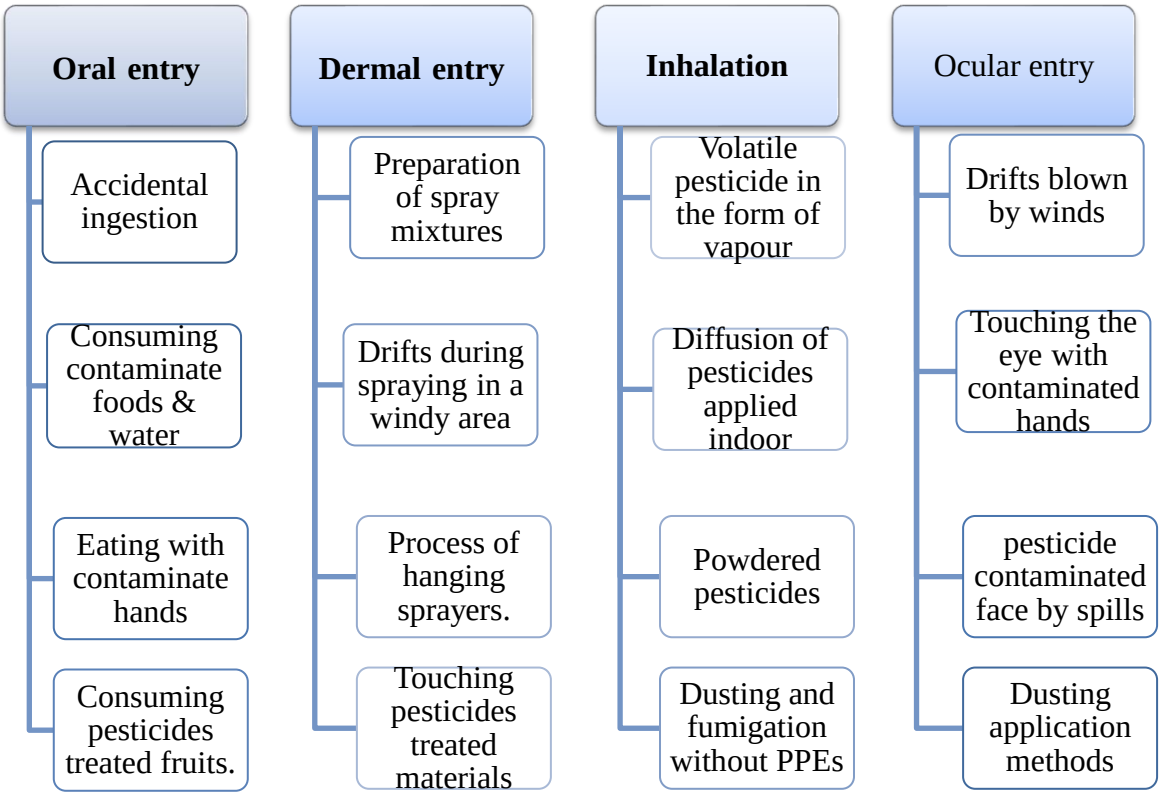

FIGURE 2. **Pathways of pesticides entry, forms and means of entry**

Symptoms of pesticide poisoning

General symptoms of pesticide poisoning and toxicity include vomiting, fatigue, unusual burning sensation on the face, headache, dizziness, irritations and diarrhoea (Roberts and Reigart, 2013). The first symptoms developed with 10-60 minutes of pesticide ingestion are diarrhoea, vomiting and abdominal pain (Roberts and Reigart, 2013). Very high and severe toxicity incidences result in convulsion, coma, pulmonary swellings, and muscle twitch. High intake of pesticide formulations with active ingredient(s) concentration of about 200-500 millilitres can result in coma and convulsion within 10 minutes. The intensity and kind of symptoms depends on the level of

poisoning. Different degree of poisoning gives different kinds of symptoms. Symptoms include acute poisoning and other chronic symptoms. Below are some common and generalized symptoms of different levels of pesticides exposure and poisonings (Figure 3) (Yadav and Devi, 2017).

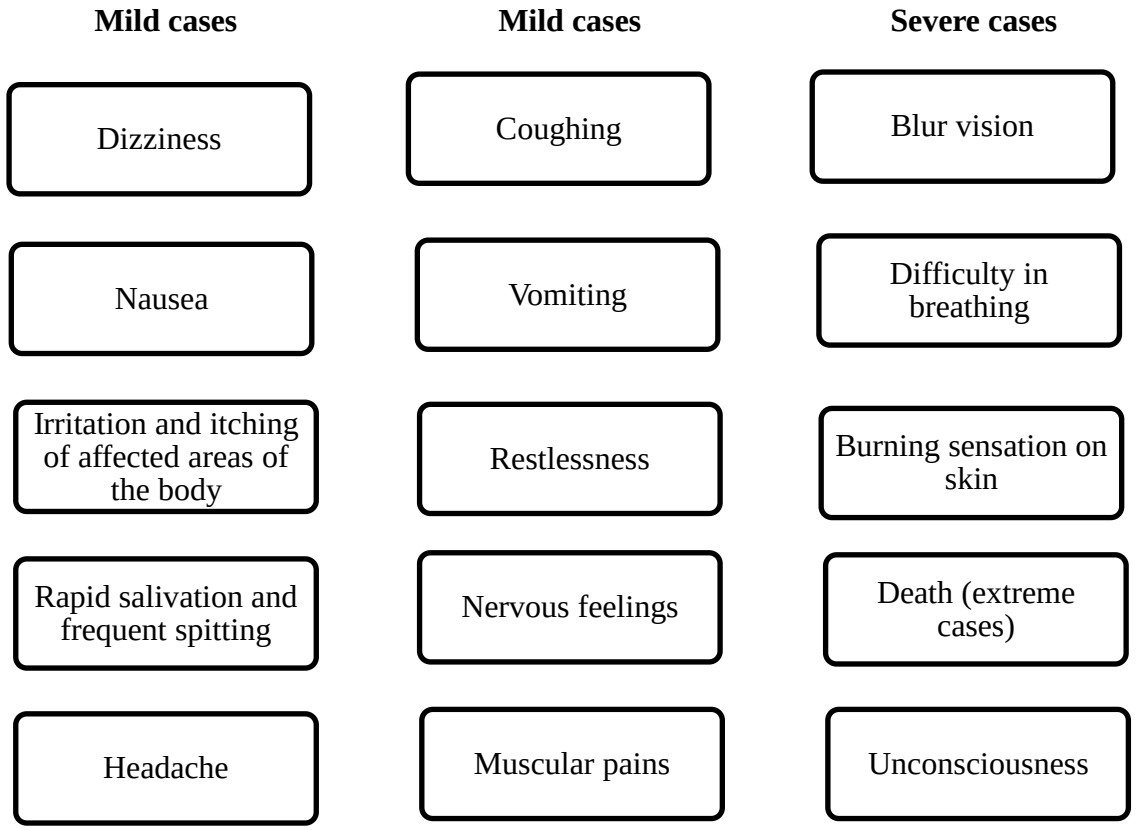

Figure 3. Some common indicator actions of poisoning by pesticides (Yadav and Devi, 2017)

Diseases induced by pesticide poisoning and contaminations

Some types of pesticides have moderate effects on the skin, whereas others pose severe and chronic problems on the brain, liver and lungs of humans (Table 5). Pesticides truncate neurochemical bio-reactions and as such become neurotoxic in the human system (Islam and Malik, 2018)). Research has revealed that, exposing a pregnant woman to pesticide may result in different kinds of congenital anomalies such as neural tube defects, cleft, orofacial and limb anomalies in a baby (Asghar *et al*., 2016). Pyrethroid group of pesticides are noted for their negative impacts on sperm production and quality (CAST, 2019). High hazardous pesticides pose functional effects on the central nervous system, disruptions of nerve cells and interfer with the physio-chemical and bio-chemical processes of neurons ((Islam and Malik, 2018)). Some pesticide disorders and system abnormalities are listed below (Table 5).

TABLE 5. **Some pesticide induced-disorders and system abnormalities**

Condition	Target point and how it occurs	Reference
Neurotoxicant	Truncates transmission processes of neurones, restricting the availability of neuro-transmitters e.g. acetylcholine	Islam and Malik (2018)
Alzheimer	High level of dementia is produce in the brain due to persistence exposure to pesticides. Disorganize hyperphosphorylation at the muscular level.	Asghar *et al*. (2016)
Oxidative pressure	Inducement of stress on the oxidation balance by pesticide metabolites through unusual degradation of antioxidants. Reactive oxygen from pesticides causes cellular impairment on DNA and proteins.	Abass *et al*. (2017); Zhang *et al*. (2019).
Axonopathy	Toxical to axon, degrading of nerve cells axons. It detaches axon from the body cells of neurone and results to poor transmission and response to stimuli.	Islam and Malik (2018)
Neuropathy	Pesticide toxicity causes death and diminishing of neurones by necrosis and apoptosis. It can leads to several brain malfunctioning conditions.	Islam and Malik (2018)
Myelopathy	Affects myelin sheaf and interferes with myelination.	Islam and Malik (2018)
Parkinson	Substania nigra neuron becomes incapable of producing dopamine, leads to absent of muscular function and coordination.	Asghar *et al*. (2016)

Management and prevention of pesticides contaminations and poisonings

Industry is striving to produce new less toxic pesticides because of several calls for interventions to curb the growing dangers and threats of pesticides' effects on the environment and human lives. New and ecological friendly techniques of combating pests such as Integrated Pest Management (IPM) strategies should be encouraged and practiced among farmers in developing nations, who are the users of highly hazardous pesticides (Robson, 2019). Zylva (2019) recommended avoidance of pesticide application for prophylactic purposes, incentivise the reduction and low usage of pesticides, enhancing the testing of pesticides, monitoring and evaluation of pesticides use, development of objective for reducing pesticides application and effects. According to the Environmental Working Group (2018), consumers are strictly advised against purchasing of non-organic

food products, as a means of averting exposure to any potential risk of pesticide residues. Pesticide applicators should use trailed machines or equipment that can be mounted on vehicles in order to reduce occupational contamination (FAO and WHO, 2020). To reduce pesticide risks and hazards, certain European Union member countries have implemented a policy that requires training and certification for every person handling, applying, consulting, distributing and operating with pesticides (European Commission, 2019). FAO and WHO (2019) postulated that countries should have bio-pesticides laws, which encourage the use of bio-pesticides and strictly regulate the use of synthetic ones. For instance, Ghana, Ethiopia, South Africa and Kenya have employed bio-pesticides in agriculture (Article 7.5 of International Code of Conduct on Pesticides Manufacturing Companies Laws). FAO and WHO (2019) further reported that, there should also be development, adoption and implementation of biological pest control measures, using naturally available and safe plant-base products. Farmers are also encouraged to adopt and use less dangerous manufactured chemical pesticides as alternatives. Farming practices that conserve natural enemies of pests while increasing yield should be encouraged among farmers (FAO and WHO, 2019).

First aid and emergency response measures for pesticides poisoning

These are immediate safety and health treatments given to persons poisoned by pesticides before they seek medical attention. These emergency treatments suppress or reduce the intensity of poisoning for a period of time. Some first aid procedure for pesticide poisoning through ingestion include immediate consumption of milk or more water while those through skin and eye contact include washing of affected part with soap and water immediately (Saleem *et al*., 2019). According to Fishel (2019), persons who come into contact with pesticides must immediately hold-opened their eyelid and wash it calmly with drips of water across. Rinse eye with clean water for about 15-20 minutes; Stimulate vomiting if required per label. Activated charcoal can be given in a powdered form; Take off clothes with pesticide contacts. Gently wash skin with much water and soap. Wrap the affected part with bandage if there is burn on the skin. Do not apply ointment or powder unless under medical prescription.

CONCLUSION

Pesticide use in modern agriculture is key for increased food and animal production as well as for control of indoor pests. Their use has translated into significant rise in agricultural outputs and the control of nuisance pests of crops, animals and humans. However, pesticides have posed acute and chronic dangers to health of man and animals, water quality, soil health, aquatic lives and other beneficial organisms. This review considered dangers associated with pesticide contaminations and poisonings, events that lead to pesticides contaminations, common symptoms and disorders of pesticides poisonings, types and classes of pesticides, groups that are vulnerable to pesticide contaminations and poisonings. It also focused on some best alternative measure to employ in order to curb hazards associated with pesticide use. Some precautionary measures and first aid tips in managing emergency cases of pesticides poisoning were also discussed. It is thus, necessary to enforce the much needed precautions and alternative measures required to mitigate global and local cases of pesticide hazards.

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