The Environmental and Health Impacts of Harmful Insecticides: A Comprehensive Review

Abul Faiz

Assistant Professor, Dept. of Zoology, Barama college, Assam, India

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Abstract - *Pesticides are either natural or chemically synthesized compounds that are used to control a variety of pests. Harmful insecticides can lead to contamination of soil and water bodies. They can harm non-target species, including beneficial insects and wildlife. Some insecticides persist in the environment for extended periods. Exposure to these insecticides can lead to acute and chronic health issues in humans. Pesticide applicators, farmers, and communities near treated areas are at higher risk. Health problems may include respiratory issues, neurological effects, and reproductive complications. This review work highlights the urgent need for safer and more sustainable pest control methods. It underscores the importance of regulation and proper pesticide handling to minimize risks. Understanding the impacts is crucial for mitigating the ecological and health consequences of harmful insecticides. Major literature reviewed in this study focused on potential uses of pesticides, classification according to their properties and toxicity and their adverse effect on natural system, human health and food products. An attempt is also made to focus on the eco-friendly management strategies for pests as a green solution.*

Key Words: **Environmental impact, Human health, Insecticides, Integrated Pest Management, Organic farming, Organochlorines, Organophosphates, Residues.**

1. INTRODUCTION:

Pest management plays a critical role in agriculture, public health, and various other industries. It involves controlling and minimizing the negative impacts of pests, such as insects, on crops, human health, and the environment. In this context, insecticides, which are chemicals designed to target and eliminate harmful insects, play a significant role. It is generally used to prevent illnesses spread by vectors, including crop protection, food preservation, and significant roles in commercial as well as food based industrial practices, i.e., aquaculture, agriculture, food processing, and storage (Mieldazys et al., 2015)[52]. Pesticides are defined by the Food and Agriculture Organization (FAO) of the United Nations as substance or mixture of substances attended for controlling, preventing, destroying any pest, animal, or human disease causing vectors, undesirable plants, or animal species affecting food production, managing, selling, storage, and transportation (World Health Organization, 2015) [88]. Insect pests can cause substantial damage to crops, leading to reduced yields and economic losses for farmers. Insecticides help to protect crops, ensuring food security and maintaining agricultural productivity. Insects like mosquitoes can transmit diseases such as malaria, Zika, and dengue. Insecticides are crucial for controlling disease vectors and safeguarding public health. Insecticides are used to protect livestock from parasites like ticks and flies, which can harm animal health and reduce meat and dairy production. While insecticides are used to combat harmful pests, their careful application is essential to maintain a balance in ecosystems by minimizing the impact on non-target species and beneficial insects. For many industries, controlling insect pests is essential to the economic viability of their operations. Insecticides are a key tool in achieving this goal. However, it is important to note that the use of insecticides must be carefully managed to mitigate potential environmental and health risks. Sustainable and responsible pest management practices are vital to address these concerns and ensure a harmonious coexistence between humans, crops, and the environment.

Investigating the harmful effects of certain insecticides is crucial for several reasons. Many insecticides can pose health risks to humans, particularly those involved in their production, application, or residing in areas where they are used. Investigating their effects helps identify and mitigate potential health hazards. Harmful insecticides can have far-reaching consequences on ecosystems. They may harm non-target species, disrupt food chains, and pollute soil and water. Understanding these effects is essential for ecological preservation. Investigating the impacts of insecticides aligns with the need for sustainable agriculture and pest management. It helps to identify eco-friendly alternatives and practices to reduce the reliance on harmful chemicals. Research findings inform regulatory bodies and policymakers about the risks associated with specific insecticides. This information can lead to better regulations and guidelines for their use. Investigative studies raise awareness among the public, farmers, and pesticide applicators about the potential dangers of certain insecticides. This can lead to more cautious and responsible use. Investigating the long-term effects of insecticides helps predict and prepare for potential issues that may emerge years after their application, such as soil and water contamination. Thus, understanding the harmful effects of certain insecticides is vital for protecting human health, preserving the environment, promoting sustainability, and guiding effective regulations. This knowledge empowers individuals and organizations to make informed choices and adopt safer pest management practices. This review work on the title "Environmental and Health Impacts of Harmful Insecticides: A Comprehensive Review" was attempted with the objectives to assess the existing research up to 2016, to highlight key findings and to emphasize significance by discussing the urgency of safer pest management methods, the importance of regulatory measures, and the need for sustainable and responsible pesticide use.

2. METHODOLOGY:

The application of insecticides has been practiced over decades to protect crops from pests. The toxicity of insecticides to environment and human is now evident, and many ecological imbalances as well as different complexities in human have been observed due to the uncontrolled application of insecticides which is, furthermore, a concern for sustainable food production. Therefore, this review aims to give an insight into the impacts of insecticide application on environment and human. In the early section of this review, a brief discussion on the role of insecticide in pest management has been added. Later on, different harmful insecticides used in agriculture and their impacts on environment and human have been extensively reviewed. In the following section, associated risks of insecticide application to food security and human nutrition have been discussed. At the end of this review, several management approaches have been pointed out to reduce insecticide exposure.

3. LITERATURE REVIEW:

The historical use and development of insecticides have a long and complex history, dating back thousands of years. The use of insecticidal chemicals dates back to ancient civilizations. Substances like sulfur, arsenic, and plant extracts were used to control pests. In China, over 2,000 years ago, predatory ants were used to control citrus pests, representing an early form of biological pest control. Since early days, pests were attempted to control with a variety of chemical compounds. For the past two millennia, insect pests have been managed with Pyrethrum, a pesticide produced from the plant *Chrysanthemum cinerariaefolium* (Unsworth, 2010) [86]. These chemicals had both advantages and drawbacks. In early 20th century, compounds like lead arsenate and Paris green were used widely. However, these chemicals were highly toxic to humans and the environment. In the middle of 20th century, DDT (dichloro-diphenyl-trichloroethane) and other organochlorines came into prominence. DDT was effective against various pests but caused environmental concerns and health issues. In late 20th century the insecticides, such as Malathion and carbaryl, were developed as alternatives to organochlorines. They were more biodegradable but still had toxicity concerns. In modern era safer and more effective insecticides like pyrethroids were developed. They are commonly used in household insect sprays and agricultural applications. According to WHO reports, the use of pesticides has increased annually in Southeast Asia, with 20% of developing nations—including Cambodia, Laos, and Vietnam—as consumer of pesticides (Schreinemachers and Tipraqsa, 2012)[73]. With an annual output of 90 thousand tons of organochlorine pesticides, including DDT and benzene hexachloride, India is one of the biggest producers of pesticides in Asia (Khan et al., 2010) [42].

The use of beneficial insects, parasitoids, and predators gained popularity as a sustainable and eco-friendly approach to pest control. Genetic modification led to crops engineered to produce insecticidal proteins, such as Bt (*Bacillus thuringiensis*) crops. These are considered more targeted and environmentally friendly. At present IPM combines various pest control methods, including insecticides, with an emphasis on minimizing environmental and health risks. Efforts are made to develop insecticides with lower toxicity, reduced environmental persistence, and specific target pest selectivity. The historical development of insecticides has been marked by a shift from toxic and persistent chemicals to more selective and environmentally friendly options. Researchers and policymakers continue to focus on finding effective, sustainable, and safe ways to manage insect pests to address the challenges of modern agriculture and public health.

3.1 TYPES OF INSECTICIDES:

The most often used criteria for pesticide classification are the mode of entry, chemical makeup, and the target it kills. On the other hand, the WHO and Globally Harmonized System (GHS) classified pesticides based on their toxicity or harmful effects, prioritizing public health. Harmful insecticides can be classified based on their chemical composition and mode of action. Based on chemical composition insecticides may be: (1) Organochlorines, which are chlorinated hydrocarbon containing five or more chlorine atoms attached to an organic compound. Due to the low purchasing cost of organochlorines, dichloro-diphenyl-trichloro-ethane (DDT), hexachloro-cyclohexane (HCH), aldrin, and dieldrin are the most used insecticides in Asia. This group of insecticides is very stable and persists in the environment for a long time (Sparling, 2016) [79]. The mode of action of this class of insecticide is that they disrupt the nervous system of insects. (2) Organophosphates, mainly esters, are derived from phosphoric acid used as pest-controlling chemicals. Parathion, malathion, diazinon, and glyphosate are widely used organophosphate insecticides. People may be exposed to these insecticides mainly through inhalation, diet, and dermal adsorption (Balali-Mood & Saber, 2012)[4]. They act by inhibiting acetyl-cholinesterase of the insects leading to nerve signal disruption. (3) Carbamates contain carbamate groups. Examples include Carbaryl and Aldicarb. Carbamates are the derivatives of carbonic acid and mostly used as insecticides. Similar to organophosphates, they inhibit acetylcholinesterase. (4) Pyrethroids are the synthetic analogs of pyrethrins, which are derived from chrysanthemum flowers. Examples include Permethrin and Cypermethrin. Two types of pyrithroids are found, Type I pyrethroids contain cyclopropane carboxylic and type II pyrethroids contain cyano group. Major type I pyrethroids are allethrin, bifenthrin, d-phenothrin, permethrin, resmethrin, tefluthrin, and tetramethrin, whereas type II pyrethroids include cyfluthrin, cyhalothrin, cypermethrin, deltamethrin, fenvalerate, fenpropathrin, flucythrinate, flumethrin, fluvalinate, and tralomethrin (Kaviraj & Gupta, 2014) [40]. This class of insecticides disrupts the nervous system of insects. Generally, pyrethroids can enter the human body through inhalation and direct skin contact (Saillenfait et al., 2015)[69]. (5) Neonicotinoids are derived from nicotine. Examples include Imidacloprid and Clothianidin. Neonicotinoid insecticides are widely used in both urban and agricultural settings around the world. Historically, neonicotinoid insecticides have been viewed as ideal replacements for more toxic compounds, like organophosphates, due in part to their perceived limited potential to affect the environment and human health. They affect the insect's nervous system by binding to nicotinic acetylcholine receptors. (6) Botanicals, these are derived from plant sources. Examples include Pyrethrum and Neem oil. Their mode of is varied, often affecting insect physiology and behavior.

On the basis of the mode of action, the insectides are classified as- (1) Contact Insecticides, they kill insects upon direct contact with the chemical. Examples include pyrethroids and diatomaceous earth. (2) Systemic Insecticides, these are absorbed by the plant, making the entire plant toxic to insects that feed on it. Neonicotinoids are an example. (3) Stomach or Ingested Insecticides, insects ingest the chemical when feeding on treated plants. Organophosphates and carbamates often act this way. (4) Growth regulators, disrupt the growth and development of insects. Insect growth regulators (IGRs) and chitin synthesis inhibitors fall into this category. (5) Neurotoxic Insecticides target the nervous system of insects, leading to paralysis or death. Organochlorines and pyrethroids are examples. (6) Repellents and Inhibitors, these substances deter insects from approaching or inhibit their feeding, such as insect repellents containing DEET.

3.2 HARMFUL IMPACT OF INSECTICIDES:

Several specific cases and events have highlighted the negative consequences of chemical insecticides. The Bhopal gas tragedy in India was caused by a chemical leak at a Union Carbide pesticide plant in 1984. It resulted in thousands of deaths and long-term health issues, underscoring the dangers of handling hazardous insecticides and industrial chemicals. The use of organo-chlorines, particularly DDT, led to the thinning of bird eggshells and a decline in populations of predatory birds like bald eagles and peregrine falcons. Legal restrictions on DDT helped in their recovery. The widespread use of neonicotinoid insecticides has been linked to honeybee population declines due to their potential role in CCD. The loss of honeybees has serious implications for pollination and food production. Farmworkers and agricultural communities are at risk of pesticide exposure. Cases of pesticide poisoning and health issues among these populations highlight the health risks associated with chemical insecticides. The presence of pesticide residues in food, including fruits and vegetables, has raised concerns about human exposure to these chemicals. This has led to calls for stricter pesticide residue regulations and organic farming practices. Overuse of certain insecticides has led to the development of insecticide-resistant pest populations. This necessitates the use of even more potent chemicals, contributing to a cycle of escalating pesticide use. The persistence of some insecticides, such as organophosphates and organochlorines, has led to soil and groundwater contamination, affecting ecosystems and drinking water sources. Insecticides often harm non-target species, including beneficial insects, birds, and aquatic life, disrupting ecological balances. These cases and events have underscored the importance of responsible pesticide use, the development of safer alternatives, and stricter regulations to minimize the negative consequences of chemical insecticides on the environment, human health, and wildlife.

3.3 ENVIRONMENTAL IMPACT:

Organophosphate insecticides can persist in soil, leading to long-term contamination. Runoff can carry organophosphates into water bodies, harming aquatic life. Birds, fish, and beneficial insects can be directly affected. Neonicotinoids have been linked to bee colony collapse disorder (CCD) and declines in pollinator populations. Runoff from treated plants can contaminate water bodies, posing risks to aquatic ecosystems. Pyrethroids can harm beneficial insects like bees and natural predators. These insecticides are toxic to aquatic organisms and can lead to water contamination. Harmful insecticides can have significant and wide-ranging effects on ecosystems, including soil, water, and wildlife:

3.3.1 Soil:

The behaviour and biological activity of pesticides in soil are determined by their physical and chemical properties, including their molecular weight, ionizability, lipophilicity, polarizability, and volatility (Beulke et al., 2004) [8]. Pesticide fate in an ecosystem of soil is generally determined by two processes: biological transformation resulting from the presence of living creatures and abiotic transformation relating to the pesticide's physicochemical qualities. The leaching process may be influenced by the chemical, physical, and biological characteristics of the soil when pesticides are used for agricultural practices (Steffens et al., 2013) [80]. Pesticides are translocated into soil and water as a result of various agricultural practices. Depending on a number of factors, such as pH, temperature, moisture, mineral and organic compound content, soil texture, climate change, and soil texture, their persistence in these environments can last for weeks, months, or even years (Gupta and Gajbhiye, 2002) [28]. While the chemical structures of pesticides govern their persistence in soil or the environment, their physical characteristics make them resistant, decreasing losses. These chemical and physical characteristics of chemical compounds are related to how they travel in aquatic and soil environments and how resilient they are in harsh environments (Pereira et al., 2016) [59]. The soil ecosystem may be deteriorated by the Insecticides, particularly persistent ones, can contaminate the soil. This contamination may last for extended periods and can negatively impact soil quality and fertility. Insecticides can disrupt soil microbial communities that are essential for nutrient cycling and maintaining soil health. Some insecticides may accumulate in soil and enter the food chain when organisms consume contaminated soil. This can result in bioaccumulation, impacting higher trophic levels. Soil-dwelling organisms like earthworms are essential for soil aeration and nutrient cycling. Insecticides can harm these organisms, disrupting the soil ecosystem.

3.3.2 Water:

Many factors, such as atmospheric precipitation and the release of raw chemical waste by the chemical or pesticide manufacturing industries into rivers and other water bodies, allow persistence organic pesticides to find their way into water bodies. Once there, the pesticides contaminate aquatic environments and spread over large distances, posing a threat to aquatic ecosystems (Socorro et al., 2016) [78]. Poorly managed agricultural operations produce pesticide contamination, which contaminates both surface and ground water. According to Khatri and Tyagi (2015) [43], it lowers the accessible drinking water's quality. The fish's skin, alimentary canal, and gills all absorb numerous contaminants, which spread to different organs and tissues and change natural and physiological processes (Banaee et al., 2011)[5]. The gills are the most contaminated organs since they are totally submerged in water. Through the gills, toxins enter the body and raise the need for oxygen. Thus, keeping an eye out for any potentially dangerous stress in the aquatic environment is crucial (Panigrahi et al., 2014)[58]. According to Stehle and Schulz (2015) [81], insecticides have the power to alter and disrupt the swimming patterns of aquatic vertebrates, including fish and amphibians, as well as slow down their rates of growth. According to Jensson et al. (2007) [32], pesticides may affect the reproductive systems of Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*). Furthermore, other research on fish exposed to the pesticide found a variety of developmental defects (Dawar et al., 2016) [15]. Numerous investigations have revealed that pyrethroids are detrimental to fish reproduction and the early phases of embryogenesis. Fish that are still young may exhibit delayed production of the egg proteins vitellogenin and choriogenin due to exposure to pyrethroids such bifenthrin and permethrin (Brander et al., 2012) [9]. It has been demonstrated that pesticides affect acetylcholinesterase (AChE) activity, which affects the nervous system and results in various neurotoxic effects in fish (neurotoxicity) (Sharbidre et al., 2011) [74]. Fish species that are impacted by pesticide exposure include *Rhamdia quelen*, *C. carpio*, *Colisa fasciatus*, *Oreochromis mossambicus*, and Labeo *rohita*. These species have also demonstrated changes in AChE activity. Fish endocrine systems are also harmed by pesticides (Brodeur et al., 2013) [10]. Fish like *Cirrhinus mrigala*, *Carassius auratus* (goldfish), and *L. rohita* may experience molecular toxicity when exposed to these chemical compounds in large quantities (Ullah et al., 2014) [85]. Histopathological analyses reveal that they negatively impact *Oncorhynchus mykiss* and *L. rohita*'s endocrine systems (Dey and Saha, 2014) [17]. Insecticides applied to crops can be carried by rainfall runoff into nearby water bodies. This can lead to water pollution and contamination. Water contamination can harm aquatic life, including fish and invertebrates. These chemicals can disrupt aquatic ecosystems and lead to fish kills. Insecticides can accumulate in aquatic organisms, potentially impacting higher trophic levels. Predatory fish, for example, may accumulate toxins from consuming contaminated prey. Some insecticides can contribute to nutrient imbalances in water bodies, leading to algal blooms that deplete oxygen and harm aquatic life.

3.3.3 Wildlife:

Although applying insecticides offers a barrier against other insect pests that feed on pods, damaged pods may not produce seeds or may be of low quality, making them inappropriate for use (Mugo, 1998) [54]. In rice and soybeans, using chitosan at an early stage of development increased plant growth and development and increased seed output (Chibu et al., 2002) [11]. Similarly Rehim et al. (2009) [67] studied on maize and beans. According to the majority of scientists, using pesticides has a negative impact on the growth and development of plants (Sharma et al., 2015) [75]. Pesticide-induced oxidative stress lowers plant proteins, chlorophyll pigments, and photosynthetic effectiveness (Xia et al., 2006) [89]. Insecticides can directly harm wildlife species that come into contact with them. Birds, mammals, and amphibians may be affected by ingesting contaminated prey or by direct exposure. Even non-lethal exposure to insecticides can have indirect effects. Reduced prey availability due to insecticide use can impact predators' food sources. Many harmful insecticides, particularly organochlorines, have been associated with eggshell thinning in birds of prey. This led to population declines in species like the bald eagle and peregrine falcon. Insecticides can harm beneficial insects like pollinators and natural predators. This can disrupt ecosystems and lead to increased pest problems. According to Liu et al. (2015) [48], pesticides break down into new chemical entities called metabolites, which can either be dangerous or non-toxic depending on their chemical makeup. Pesticides linger in the soil for a long time and have a negative impact on the soil and ecosystem because of the attraction between soil particles and pesticides in sorption systems (attraction determined by soil organic matter and soil texture) (Qin et al., 2014) [62]. Harmful insecticides can disrupt the food chain and ecological balance. When insecticides are used, they can directly harm species at the bottom of the food chain, such as insects and plants. Insecticides may target herbivorous insects, disrupting the primary consumers in the food web. Insecticides can reduce or eliminate populations of herbivorous insects and other prey species. This can disrupt the availability of food for predators and higher trophic levels. The loss of prey species affects predators at higher trophic levels. Predators may suffer due to a decreased food supply, leading to reduced reproduction and survival rates. Insecticides can accumulate in the tissues of organisms. Predators at the top of the food chain, such as birds of prey or fish, may accumulate high levels of toxins through the consumption of contaminated prey. Insecticides often harm non-target species, including beneficial insects, amphibians, and small mammals. These unintended effects can disrupt the ecological balance by reducing predator-prey relationships and beneficial ecological interactions. Some insecticides can alter the behavior of species, making them more vulnerable to predation. For example, an insecticide may affect the foraging behavior of pollinators, reducing their efficiency in pollinating plants. Overuse of certain insecticides can lead to the development of resistant pest populations. In response, even more potent chemicals are often used, further disrupting the ecological balance. Insecticides that lead to nutrient imbalances in aquatic ecosystems can contribute to algal blooms. These blooms can deplete oxygen in water bodies, harming aquatic life and disrupting the food chain. Insecticides may disproportionately harm natural predators, such as ladybugs, spiders, or parasitoids. This can allow pest populations to increase, causing imbalances in ecosystems. The cumulative impacts of harmful insecticides on various species and trophic levels can lead to a decline in biodiversity, which can affect the overall health and resilience of ecosystems.

3.4 IMPACT ON HUMAN HEALTH:

According to reports, the primary mechanism of organophosphate toxicity in subchronic or chronic exposure is the production of oxidative stress (Ranjbar, 2005) [65]. In humans and experimental animals, acute and chronic poisoning with organophosphate chemicals induces oxidative stress (Abdollahi et al. 2004) [1]. One of the oxidative stress mechanisms in organophosphate intoxication is hyperglycemia (Rahimi et al. 2006) [64]. Humans who are acutely poisoned by organophosphates may have symptoms such as vomiting, nausea, and disruption of the nervous system. Extended exposure has been associated with a higher risk of cancer as well as neurological and developmental problems. Exposure to neonicotinoid residues in food is possible for humans. Humans may experience neurotoxic consequences from neonicotinoids, although occupational exposure is the main cause of risk. Humans who utilise pyrethroids may have skin and eye discomfort. Pesticide applicators may experience respiratory issues if they inhale pyrethroids. Over time, the exposure to organochlorine pesticides may cause immune system disorders, cancer, birth defects, cognitive impairment, and reproductive issues (Agbeve et al., 2014) [2]. There are numerous studies and pieces of data that link toxic insecticides to health hazards. Although the chemical mechanism of quaternary nitrogen compounds, like paraquat, is still unclear, they are linked to neurological illnesses like Parkinson's (Franco et al., 2010) [22]. Similarly, the acetylcholinesterase (AChE) activity is inhibited by the pesticide group of carbamates, which is utilised as a neurotoxicity biomarker (Gupta et al., 2016)[30]. Numerous studies indicate that organo-phosphorus raises the risk of coronary artery disease and decreases paraoxonase activity (Kabir et al., 2015) [36]. Pyrethroid metabolites are associated with increased sperm DNA damage and decreased semen quality in human urine (Meeker et al., 2008) [51]. The likelihood of sex chromosomal disomy in sperm nuclei is also increased by non-occupational exposure to pyrethroids (Radwan et al. 2015) [63]. Direct exposure to pesticides has been shown to increase a person's risk of developing a number of human cancers, including those of the head, neck, breast, thyroid, brain, colon, pancreas, lung, leukaemia, prostate, non-Hodgkin lymphoma, and ovarian (Obiri et al., 2013) [56]. Research has shown that eating food tainted with pesticide residues increases toxicity more than drinking or breathing in tainted air or water (Margni et al., 2002) [49]. According to Yadav et al. (2015) [90], pesticides have the ability to mimic or oppose natural hormones, which can upset hormonal balance, lower immunity, cause cancer, and cause other issues relating to reproduction. Pesticide-exposed individuals who live close to farms or agricultural fields, work in pest control, are employed in the agricultural industry, or are exposed to household pesticides are among the groups most at risk of developing health problems as a result of pesticide exposure (Ernst, 2002) [19]. Permethrin and Sumithrin are major causes of headaches, tremors, convulsions, and asthma attacks; in more severe cases, they can be fatal. Some synthetic insecticides, including pyrethroid, which are used to control mosquitoes, are also known to trigger asthma episodes (Amaral, 2014) [3]. According to research, pre- or post-processing procedures can effectively lower the amount of pesticides present in the finished product. But occasionally, processing—like when oil is extracted from oil seeds, for example—helps accumulate pesticide residues (Kaushik et al., 2009) [39]. Pesticides can be metabolised, eliminated, stored, or bioaccumulated in body fat within the bodies of humans and animals (Pirsaheb et al. 2015) [60]. Chemical pesticides have been linked to a wide range of detrimental health impacts, including neurological, respiratory, reproductive, gastrointestinal, dermatological, and endocrine disorders (Mnif et al. 2011) [53]. Moreover, hospitalisation and death may occur from high occupational, unintentional, or purposeful pesticide exposure (Gunnell et al. 2007) [23]. The unchecked usage of the insecticide DDT created several problems for the environment and public health (Turusov et al. 2002) [84]. According to Turusov et al. (2002), DDT is a chemical that is widely present in all living things on Earth, with the majority of its body burden being stored as fat. Additionally, there is evidence that DDT and its metabolite, p-dichlorodiphenyldichloroethylene, or DDE, may have carcinogenic and endocrine disrupting properties. Children's neurodevelopment has been linked to prenatal exposure to both DDT and DDE (Eskenazi et al. 2006) [20]. Furthermore, a recent study connected DDE to hepatic lipid impairment in rats (Rodríguez-Alcala et al. 2015) [68]. Health effects, including endocrine disorders (Mnif et al. 2011) [53], effects on embryonic development (Eskenazi et al. 2006) [20], lipid metabolism (Karami-Mohajeri et al. 2011) [38], and haematological and hepatic alterations have been linked to the general class of organochlorine pesticides. Organophosphate pesticides have also been linked to genotoxic effects (Li et al. 2015) [46], effects on mitochondrial function, which result in cellular oxidative stress and issues with the nervous and endocrine systems, decreases in insulin secretion, disruption of normal cellular metabolism of proteins, carbohydrates, and fats, and effects on the function of cholinesterase enzymes (Jaga and Dharmani, 2003) [33]. According to population-based studies, there may be a connection between exposure to organo-phosphorus pesticides and major health consequences such as dementia (Lin et al. 2015) [47], cardiovascular diseases harm to the male reproductive system (Jamal et al. 2015) [34], effects on the nervous system (Jaga and Dharmani, 2003) [33], and a potential higher risk of non-Hodgkin's lymphoma (Waddell et al. 2001) [87]. Moreover, there is evidence linking prenatal exposure to organophosphates to shortened gestational duration (Eskenazi, 2004) [21] and neurological issues in offspring (Rauh et al. 2015) [66]. The most common herbicide in use in modern agriculture is glyphosate, whose safety is the topic of an ongoing scientific debate (Gasnier et al. 2009) [23]. This is especially true since the introduction of glyphosate-tolerant genetically modified crops, like some varieties of maize and soybean (Baylis, 2000)[7]. Because of the simultaneous exposure to glyphosate and the phytoestrogen "genistein," a common isoflavone found in soybeans and soybean products, its widespread use in genetically modified soybean cultivation has sparked concerns about potential synergistic estrogenic effects. Endocrine-disrupting action has been observed with glyphosate (Thongprakaisang et al. 2013)[83]. Glyphosate can disturb the endocrine system, impact human erythrocytes in vitro (Kwiatkowska et al. 2014) [45], and increase the risk of cancer in mice (George et al. 2010)[25]. Moreover, it is thought to severely disrupt the shikimate pathway, which is present in human gut microbes as well as in plants and microorganisms. The supply of critical amino acids to the human organism may be impacted by this interruption (Samsel and Seneff, 2015) [70]. According to Thongprakaisang et al. (2013) [83], commercial glyphosate formulations are thought to be more hazardous than the active ingredient alone. Herbicides containing glyphosate, including the well-known "Roundup," can damage DNA and interfere with hormone production in rat testicular cells (Clair et al. 2012) [13] and human cell lines (Gasnier et al. 2009) [23]. It can cause harm to cultured human cutaneous cells (Gehin et al. 2006) [24], induce cell death in rat testicular cells (Clair et al. 2012) [13], and induce cell death in experimental animal testicular cells. Hedberg and Wallin (2010) [31] have provided evidence that suggests they may also have an impact on the cytoskeleton and intracellular transport. A recent study looked at the potential link between genetically modified crops, glyphosate, and declining health in the United States. Concerning potential links between glyphosate use and a number of health impacts and disorders, including cancer, diabetes, hypertension, strokes, autism, kidney failure, Parkinson's, and Alzheimer's diseases, were brought up by correlation analyses (Swanson et al. 2014)[82]. Moreover, glyphosate may be linked to gluten intolerance, a condition linked to deficiencies in important trace metals, problems with reproduction, and a higher chance of developing non-Hodgkin's lymphoma (Samsel and Seneff, 2015)[70]. Another class of chemical pesticides that have been linked to endocrine disruption (Mnif et al., 2011) [53], potential reproductive disorders (Jamal et al., 2015) [34], and impacts on cellular metabolic processes and mitochondrial function (Karami-Mohajeri and Abdollahi, 2011)[38] are carbamate pesticides, which include aldicarb, carbofuran, and ziram. Additionally, studies have shown that carbamate insecticides can result in non-Hodgkin's lymphoma (Zheng et al. 2001) [91], higher risk for dementia (Lin et al. 2015) [47], and neurobehavioral consequences. Research on extended exposure to carbamate insecticides and case studies of such exposure yielded conflicting findings (Dickoff et al., 1987)[18]. A thorough investigation into the toxicology of the popular insecticide carbaryl reveals a range of neurotoxic and reversible neurobehavioral effects in vertebrates, all of which are connected to acute poisoning symptoms (Cranmer, 1986)[14]. It has been shown that the carbamate, carbofuran, increases oxidative stress in the rat brain by lowering antioxidant defence and causing lipid peroxidation (Kamboj et al. 2006) [37]. Compared to organophosphates, carbamates pose a lower risk of exposure to humans. Another class of chemical pesticides linked to reproductive toxicity and endocrine disruption consequences are triazines, which include atrazine, simazine, and ametryn (Mnif et al. 2011)[53]. Furthermore, a potential statistical correlation between the prevalence of breast cancer and triazine herbicides was discovered (Kettles et al. 1997) [41]. The most well-known triazine is atrazine, an herbicide that is used extensively and has been linked to cytotoxicity (Liu et al. 2006) [48], dopaminergic effects (Li et al. 2015) [46], and oxidative stress (Jin et al. 2014) [35]. According to Kolaczinski et al. (2004) [44], synthetic pyrethroids like sumithrin, permethrin, and fenvalerate are among the safer insecticides now on the market for use in agriculture and public health. Nonetheless, research has shown that they can exhibit endocrine-disrupting action (Jaensson et al. 2007) [32] and influence reproductive parameters, such as reproductive behaviour, in laboratory animals. According to a study (Dewailly et al., 2014) [16], pyrethroids were discovered in human breast milk, and their metabolites were discovered in urine. Insecticide exposure, especially among agricultural workers and pesticide applicators, has been linked to acute poisoning with symptoms such as nausea, vomiting, diarrhea, and nervous system disruptions. Data from poison control centers and health agencies document thousands of pesticide-related poisonings and incidents each year, indicating the immediate health risks. Long-term exposure to organophosphates and organochlorines has been associated with neurological effects, including cognitive impairments, depression, and neurodevelopmental issues, particularly in children. Certain insecticides, when inhaled, can lead to respiratory problems and exacerbate conditions like asthma. Some studies suggest that exposure to certain insecticides may impact reproductive health, increasing the risk of infertility, birth defects, and developmental disorders in offspring. The International Agency for Research on Cancer (IARC) has classified some insecticides, such as glyphosate, as "probably carcinogenic to humans." Pesticide exposure has been associated with an increased risk of various cancers, including non-Hodgkin lymphoma. Certain insecticides with endocrine-disrupting properties may be linked to hormonal imbalances, affecting reproductive health and increasing the risk of hormone-related diseases. Agricultural workers who handle insecticides face elevated health risks. Long hours of exposure can lead to higher incidents of pesticide-related illnesses. Residues of harmful insecticides in food products pose a potential health risk to consumers. Regular monitoring of pesticide residues in food is conducted to ensure safety standards are met. Insecticide runoff into water sources can lead to the contamination of drinking water. Prolonged exposure to low levels of insecticides in drinking water may pose health concerns. Long-term exposure to certain insecticides, such as organo-phosphates and organo-chlorines, has been associated with neurological effects. These can include cognitive impairments, memory problems, depression, and nervous system disruptions. Clinical study has demonstrated that the Gulf War-deployed veterans exposed to sarin and cyclosarin at Khamisiyah suffered impaired fine psychomotor dexterity, reduced visuo-spatial abilities and deficits in motor function and coordination (Proctor et al. 2006) [61]. After the Tokyo subway sarin attack, a chronic decline of psychomotor function existed in 23 subway workers exposed to sarin for 7 years. The high-exposure subway workers had a significantly slower performance of the finger tapping tests of both the dominant and non-dominant hands than control group (Gullapalli et al. 2010) [26]. In another clinical study, most of the victims of the Tokyo subway sarin attack were found to have long-lasting somatic complaints (such as gastrointestinal problems, constipation, heartburn, nausea, vomiting, colitis, migraines, headaches, backaches, and skin disorders) at 5-6 years after poisoning. The long lasting somatic complaints and decreased psychomotor function of the victims exposed to organophosphates may be associated with neuronal damage in the cortex and thalamus (Nozaki et al. 1995) [55]. Some insecticides are suspected of affecting reproductive health. Prenatal exposure has been linked to birth defects, developmental disorders, and fertility problems in both males and females. Results indicated that increase of insecticides in blood level in vertebrates causes reproductive dysfunction and suggested that for human beings food like fish, chick and goat containing beyond permissible limit of insecticides must be avoided (Singh et al. 2008) [76]. Consumption of high pesticide residue fruits and vegetables was associated with lower total sperm count, ejaculate volume and percentage of morpho-logically normal sperm among men attending a fertility clinic (Chiu et al. 2015)[12]. Organochlorine pesticide residue levels were reported significantly higher in the cancer patients (Pandit and Sahu, 2002; Mathur, et al. 2008) [57, 50].

3.5 REGULATORY ASPECTS:

Government regulations play a crucial role in controlling harmful insecticides to protect public health, the environment, and the well-being of ecosystems. Before any insecticide can be sold or used, it typically goes through a rigorous registration process with a government agency. During this process, the agency reviews extensive safety data, efficacy, and environmental impact assessments provided by the manufacturer. Government agencies establish approved uses and limitations for each registered insecticide. These include application rates, methods, and timing to ensure safe and effective use. Government agencies set maximum residue limits (MRLs) for insecticide residues in food products. These MRLs ensure that the levels of pesticide residues in food are safe for consumers. Violations of these limits can lead to regulatory action and product recalls. Regulations are put in place to protect workers who handle insecticides. These standards cover aspects like protective clothing, training, handling procedures, and emergency response measures. Government agencies often promote integrated pest management (IPM) as an approach to minimize insecticide use and encourage more environmentally friendly and sustainable pest control practices. Regulatory agencies require manufacturers to provide detailed information on the labels of insecticide products. This includes instructions for use, safety precautions, first-aid measures, disposal instructions, and potential hazards. Regulatory agencies may require ongoing monitoring and mitigation measures to prevent insecticides from contaminating water bodies, harming non-target species, and disrupting ecosystems. In response to scientific evidence and concerns about specific insecticides, regulatory agencies have the authority to ban or restrict their use. For example, DDT was banned in many countries due to its environmental and health risks. Government agencies often work to educate the public, agricultural workers, and pesticide applicators about the safe use of insecticides, potential risks, and how to report incidents or adverse effects. Thus Government regulations are designed to strike a balance between allowing the use of insecticides for effective pest control and safeguarding the health of humans and the environment. They help ensure that insecticides are used responsibly, with an emphasis on minimizing risks and environmental impacts. Compliance with these regulations is crucial to protect individuals, ecosystems, and the broader community. Several international agreements and organizations monitor and limit the use of chemical insecticides to address global environmental and health concerns. The Stockholm Convention, administered by the United Nations Environment Programme (UNEP), Food and Agricultural Organization (FAO), a specialized agency of the United Nations, World Health Organization (WHO), another specialized UN agency, the IPPC (International Plant Protection Convention), administered by the Food and Agriculture Organization (FAO) etc. addresses the international spread of pests and diseases and has guidelines for the safe and effective use of plant protection products, including insecticides.

3.6 ALTERNATIVES AND SOLUTIONS:

Several alternative, more environmentally friendly pest management methods can be employed to reduce the reliance on chemical insecticides and promote sustainable pest control. These methods often aim to minimize harm to the environment, non-target species, and human health. Bio-pesticides are biodegradable so no harmful residues are produced and are eco-friendly. Bio-pesticides encompass a broad array of microbial pesticides, bio-chemicals derived from micro-organisms and other natural sources that confer protection against pest damage. Some insect repellents can also be used for the prevention of pesticide residues accumulation in the food grains, vegetables and fruits (Gupta et al. 2010) [29]. Natural pesticides such as extracts and compounds from neem tree are also very useful for the prevention of pesticide residues accumulation in the food products (Schmutterer, 1990) [72]. Integrated Pest Management (IPM) is a comprehensive approach that combines various strategies to manage pests. It emphasizes prevention, monitoring, and the use of biological, cultural, and physical control methods before resorting to chemical insecticides. Crop rotation viz. alternating the crops planted in a field can disrupt pest life cycles and reduce the buildup of specific pests. Growing multiple crop species together can deter pests and enhance biodiversity, making ecosystems more resilient. Physical barriers like nets or screens can protect crops from pests. Various types of traps, such as pheromone traps or sticky traps, can be used to capture pests. Natural product like neem oil is derived from the neem tree and can act as a natural insecticide. Planting crops at optimal times can reduce exposure to specific pests. Proper removal and disposal of crop residues can reduce overwintering pests. Developing pest-resistant crop varieties through selective breeding or genetic modification can reduce the need for insecticides. Organic farming relies on natural and organic inputs, avoiding the use of synthetic chemical insecticides. According to standard meta-analyses the frequency of occurrence of detectable pesticide residues was four times higher in non-organic crops than organic crops (Baranski et al. 2014) [6]. There is evidence that indicated organic food consumption can reduce exposure to pesticide residues in food (Smith et al. 2012) [77]. Healthy soils and well-rotted compost can enhance plant resilience to pests. Educating farmers and agricultural workers on sustainable pest management practices is crucial for successful adoption. In public health, strategies like the use of mosquito nets, draining standing water, and larvicide treatments are more environmentally friendly than widespread spraying of insecticides. These alternative pest management methods not only reduce the reliance on harmful chemical insecticides but also contribute to more sustainable and environmentally friendly agricultural and pest control practices. They prioritize long-term pest management and the protection of ecosystems, wildlife, and human health.

4. RESULT AND DISCUSSION:

The implications of the harmful effects discussed in the study "The Environmental and Health Impacts of Harmful Insecticides: A Comprehensive Review" are significant and multifaceted. The harmful effects of insecticides on non-target species, including beneficial insects and wildlife, can lead to declines in biodiversity. This can disrupt ecosystem balance and resilience. The contamination of water bodies and soils with insecticides can have long-lasting environmental consequences. It can harm aquatic life, contaminate drinking water, and lead to soil degradation. Insecticides can disrupt the food web and ecological balance. The decline of certain species, such as pollinators or natural predators, can lead to increased pest problems and imbalances in ecosystems. The persistence and bioaccumulation of harmful insecticides in the environment can lead to long-term contamination and contribute to ecological risks. The immediate health risks associated with insecticide exposure include acute poisoning with symptoms such as nausea, vomiting, and respiratory distress. Long-term exposure to harmful insecticides has been linked to neurological and developmental disorders, respiratory problems, increased cancer risk, and other chronic health issues. Agricultural workers, pesticide applicators, and other individuals with regular exposure to insecticides face elevated health risks, including occupational illnesses and long-term health issues. The presence of insecticide residues in food products poses a risk to consumers, particularly when exposure is chronic and low-level. The use of insecticides in public health programs, such as mosquito control, is essential for disease prevention but requires careful management to avoid adverse health effects. The implications of these harmful effects underscore the need for responsible pesticide use, strict regulations, and the development and adoption of safer alternatives. They also highlight the importance of public education, awareness, and the adoption of more sustainable pest management practices, such as Integrated Pest Management (IPM) and organic farming. Minimizing the environmental and health impacts of insecticides is critical for the well-being of ecosystems, wildlife, and human populations.

The trade-offs between pest control and environmental and human health concerns are complex and often require careful consideration. Balancing effective pest control with minimizing negative impacts on the environment and human health involves several key trade-offs. The use of potent chemical insecticides can be highly effective in quickly eliminating pests and protecting crop yields. However, this may come at the cost of greater environmental contamination. Environmentally friendly pest control methods, such as biological control or cultural practices, may have a lower immediate impact on ecosystems but might require more time to achieve pest control. Chemical insecticides can provide rapid pest control, protecting crops and reducing immediate economic losses. However, this approach may not be sustainable in the long term due to pesticide resistance and ecological damage. Sustainable pest management practices prioritize long-term ecosystem health and agricultural sustainability but may require more investment in research, monitoring, and adoption of integrated approaches like IPM. The use of chemical insecticides can lead to higher profits in the short term, especially in commercial agriculture. Increased yields can result in more significant financial gains. Overreliance on chemical pesticides can pose risks to human health, including farmworkers and consumers. These risks may result in increased healthcare costs and environmental cleanup expenses. Chemical insecticides are effective for immediate pest control but may leave behind residues in food, water, and soil. These residues can pose health and environmental risks. Implementing strategies to manage pesticide residues, including careful application and monitoring, can help reduce the risks but may not provide the same level of immediate control. Chemical insecticides can boost crop yields and food production, addressing global food security concerns. However, this comes at the cost of potential harm to the environment. Sustainable pest management practices prioritize environmental conservation and preservation. While these approaches may not maximize immediate yields, they help maintain long-term ecosystem health and resilience. Balancing these trade-offs often involves making informed decisions based on specific contexts, the type of crop or pest, and local conditions. Integrated approaches, such as IPM, aim to strike a balance by considering the full range of factors involved in pest control while minimizing harm to the environment and human health. Ultimately, it is important to prioritize sustainable and responsible pest management practices to mitigate the negative consequences of pest control measures. Future research directions in the field of harmful impacts of chemical insecticides on the environment and human health can help us better understand these issues and develop strategies to mitigate the negative effects. Conducting regular and comprehensive monitoring of pesticide residues in food products, water sources, and soil to assess exposure risks and identify emerging concerns is a very important field to be addressed in coming days. It is better to investigate the toxicological properties of both existing and newly developed insecticides to understand their specific modes of action and potential health risks. Long-term epidemiological studies should be conducted to assess the chronic health effects of pesticide exposure, particularly among agricultural workers and communities in close proximity to pesticide use. Ecological consequences of insecticides should be investigated on non-target species, including beneficial insects, birds, and aquatic life. It is very important to increase the number of research and promote sustainable and alternative pest management methods, such as biological control, genetic resistance, and precision agriculture. The success and challenges of implementing integrated pest management (IPM) strategies in various agricultural systems should be studied. Invest in research to develop and assess the safety and efficacy of new, more environmentally friendly insecticides. Future research in these areas can help guide policies, practices, and innovations that lead to a more sustainable and safer approach to pest management, protecting both the environment and human health.

5. CONCLUSION:

The key findings of this study on harmful insecticides underscore the environmental and health risks associated with their use. These risks include the contamination of water and soil, harm to non-target species, acute and chronic health effects in humans, and potential long-term ecological disruptions. Raising awareness about harmful insecticides is crucial for several reasons. Increased awareness can lead to more responsible insecticide use, reduced contamination of ecosystems, and the preservation of biodiversity. Awareness campaigns can inform the public about the risks of pesticide residues in food, occupational hazards, and the importance of safe handling and disposal. Raising awareness promotes the adoption of alternative pest management methods, such as integrated pest management (IPM) and organic farming, which are less harmful to the environment and health. Public awareness can drive changes in pesticide regulations and encourage stricter enforcement of existing laws, leading to safer and more sustainable pest control practices. Informed consumers can make choices that support sustainable and responsible agriculture, influencing market demand for safer food products. Awareness can spur research and innovation in the development of safer insecticides and alternative pest control technologies. In conclusion, advocating for stricter regulations and sustainable pest management practices is essential for safeguarding the environment, public health, and the future of agriculture. It promotes responsible pesticide use, innovation, and the adoption of environmentally friendly alternatives, contributing to a more resilient and sustainable food production system.

REFERENCES

[1] M. Abdollahi, A. Rainba and S. Shadnia, "Pesticide and oxidative stress: a review," Med Sci Monitor 10(6), 2004, RA141-RA147.

[2] S. Agbeve, P. Osei-Fosu, and D. Carboo, "Levels of organochlorine pesticide residues in *Mondia whitei*, a medicinal plant used in traditional medicine for erectile dysfunction in Ghana," Int. J. Adv. Agric. Res. 1, 2014, pp. 9–16.

[3] A. F. Amaral, "Pesticides and asthma: Challenges for epidemiology," Front. Public Health, 2014, 2:6. doi: 10.3389/fpubh.2014.00006

[4] M. Balali-Mood and H. Saber, "Recent advances in the treatment of organophosphorous poisonings," Iranian Journal of Medical Sciences, 2012, 37-74.

[5] M. Banaee, A. Mirvaghefi, B. M. Amiri, G. Rafiee and B. Nematdost, "Hematological and histopathological effects of diazinon poisoning in common carp (*Cyprinus carpio*)," J. Fish, 64, 2011, pp. 1–12.

[6] M. Baranski, D. Srednicka-Tober and N. Volakakis, "Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses," Bri J Nutr, 112(5), 2014, pp. 794-811.

[7] A. D. Baylis, "Why glyphosate is a global herbicide: strengths, weaknesses and prospects," Pest Manag Sci, 56, 2000, pp. 299–308. doi: 10.1002/ (SICI) 1526-4998(200004)56:43.0.CO; 2-K

[8] S. Beulke, C. D. Brown, C. J. Fryer and W. Van Beinum, "Influence of kinetic sorption and diffusion on pesticide movement through aggregated soils," Chemo, 57, 2004, pp. 481–490. doi: 10.1016/j.chemosphere.2004.06.026

[9] S. M. Brander, G. He, K. L. Smalling, M. S. Denison and G. N. Cherr, "The in vivo estrogenic and in vitro anti-estrogenic activity of permethrin and bifenthrin," Environ. Toxicol. Chem. 31, 2012, pp. 2848–2855. doi: 10.1002/etc.2019

[10] J. C. Brodeur, A. Sassone, G. N. Hermida and N. Codugnello, "Environmentally-relevant concentrations of atrazine induce non-monotonic acceleration of developmental rate and increased size at metamorphosis in *Rhinella arenarum* tadpoles," Ecotoxicol. Environ. Saf., 92, 2013, pp. 10–17. doi: 10.1016/ j.ecoenv.2013.01.019

[11] H. Chibu, H. Shibayama and S. Arima, "Effects of chitosan application on the shoot growth of rice and soybean," Jpn. J. Crop Sci., 71, 2002, pp. 206–211. doi: 10.1626/ jcs.71.206

[12] Y. H. Chiu, M. C. Afeiche and A. J. Gaskins, "Fruit and vegetable intake and their pesticide residues in relation to semen quality among men from a fertility clinic," Hum Reprod, 30(6), 2015, pp. 1342-1351.

[13] E. Clair, R. Mesnage, C. Travert and G. E. Seralini, "A glyphosate-based herbicide induces necrosis and apoptosis in mature rat testicular cells in vitro, and testosterone decrease at lower levels," Toxicol In Vitro, 26, 2012, pp. 269–79. doi:10.1016/j.tiv.2011.12.009

[14] M. F. Cranmer, "Carbaryla toxicological review and risk analysis," Neurotoxicol., 7(1), 1986, pp. 247-328.

[15] F. U. Dawar, A. Zuberi, A. Azizullah and M. N. K. Khattak, "Effects of cypermethrin on survival, morphological and biochemical aspects of rohu (Labeo rohita) during early development," Chemo 144, 2016, pp. 697–705. doi: 10.1016/j.chemosphere.2015.09.007

[16] E. Dewailly, M. Forde, L. Robertson, N. Kaddar, E. A. L. Sidi, S. Cote, E. Gaudreau, O. Drescher and P. Ayotte, "Evaluation of pyrethroid exposures in pregnant women from 10 Caribbean countries," Environment International, 63, 2014, pp. 201–206.

[17] C. Dey and S. Saha, "A comparative study on the acute toxicity bioassay of dimethoate and lambda-cyhalothrin and effects on thyroid hormones of freshwater teleost fish *Labeo rohita* (Hamilton)," Int. J. Environ. Res., 8, 2014, pp. 1085–1092. doi: 10.22059/IJER.2014.802

[18] D. J. Dickoff, O. Gerber and Z. Turovsky, "Delayed neurotoxicity after ingestion of carbamate pesticide," Neuro. 37(7), 1987, pp. 1229-1231.

[19] P. Ernst, "Pesticide exposure and asthma," Am. J. Respir. Critic. Care Med., 165, 2002, pp. 563–564. doi: 10.1164/ ajrccm.165.5.2201001c

[20] B. Eskenazi, A. R. Marks, A. Bradman, L. Fenster, C. Johnson and D. B. Barr, "In utero exposure to dichloro-diphenyl-trichloro-ethane (DDT) and dichloro-diphenyl-dichloro-ethylene (DDE) and neurodevelopment among young Mexican American children," Pediatrics, 118, 2006, pp. 233–41. doi: 10.1542/ peds.2005-3117

[21] B. Eskenazi, K. Harley, A. Bradman, E. Weltzien, N. P. Jewel and D. B. Barr, "Association of in Utero organophosphate pesticide exposure and foetal growth and length of gestation in an agricultural population," Environ Health Perspect, 112, 2004, pp. 1116–1124. doi:10.1289/ehp.6789

[22] R. Franco, S. Li, H. Rodriguez-Rocha, M. Burns and M. I. Panayiotidis, "Molecular mechanisms of pesticide-induced neurotoxicity: relevance to Parkinson's disease," Chem. Biol. Interact., 188, 2010, pp. 289–300. doi: 10.1016/j.cbi.2010.06.003

[23] C. Gasnier, C. Dumont, N. Benachour, E. Clair, M. C. Chagnon and G. E. Seralini, "Glyphosate-based herbicides are toxic and endocrine disruptors in human cell lines," Toxicology, 262, 2009, pp. 184–91. doi: 10. 1016/ j.tox.2009.06.006

[24] A. Gehin, C. Guyon and L. Nicod, "Glyphosate-induced antioxidant imbalance in HaCaT: the protective effect of Vitamins C and E," Environ Toxicol Pharmacol, 22, 2006, pp. 27–34. doi:10.1016/j.etap.2005.11.003

[25] J. George, S. Prasad, Z. Mahmood and Y. Shukla, "Studies on glyphosate-induced carcinogenicity in mouse skin: a proteomic approach," J Proteomics, 73, 2010, pp. 951–64. doi:10.1016/j.jprot.2009.12.008

[26] R. P. Gullapalli, Y. Aracava and J. Zhuo, "Magnetic resonance imaging reveals that galantamine prevents structural brain damage induced by an acute exposure of guinea pigs to soman," Neurotoxicol, 31(1), 2010, pp. 67-76.

[27] D. Gunnell, M. Eddleston, M. R. Phillips and F. Konradsen, "The global distribution of fatal pesticide self-poisoning: systematic review," BMC Public Health, 7, 2007, pp. 357. doi: 10.1186/1471-2458-7-357

[28] S. Gupta and V. T. Gajbhiye, "Effect of concentration, moisture and soil type on the dissipation of flufenacet from soil," Chemo, 47, 2002, pp. 901–906. doi: 10.1016/ S0045-6535(02)00017-6

[29] S. Gupta and A. K. Dikshit, "Biopesticides: An eco-friendly approach for pest control," J Biopest, 3(1), 2010, pp. 186-188.

[30] V. K. Gupta, A. Pathak, N. J. Siddiqi and B. Sharma, "Carbofuran modulating functions of acetylcholine-esterase from rat brain in vitro," Adv. Biol., 2016, 3760967. doi: 10.1155/2016/3760967

[31] D. Hedberg and M. Wallin, "Effects of Roundup and glyphosate formulations on intracellular transport, microtubules and actin filaments in Xenopus laevis melanophores," Toxicol In Vitro, 24, 2010, pp. 795–802. doi: 10.1016/j. tiv.2009.12.020

[32] A. Jaensson, A. P. Scott, A. Moore, H. Kylin and K. H. Olsen, "Effects of a pyrethroid pesticide on endocrine responses to female odours and reproductive behaviour in male parr of brown trout (*Salmo trutta* L.)," Aquat. Toxicol., 81, 2007, pp. 1–9. doi: 10.1016/j.aquatox. 2006. 10.011

[33] K. Jaga and C. Dharmani,"Sources of exposure to and public health implications of organophosphate pesticides," Rev Panam Salud Publica, 14, 2003, pp. 171–185. doi: 10.1590/S1020-49892003000800004

[34] F. Jamal, Q. S. Haque, S. Singh and S. Rastogi, "The influence of organophosphate and carbamate on sperm chromatin and reproductive hormones among pesticide sprayers," Toxicol Ind Health, 2015, pp.1–10. doi: 10.1177/0748233714568175

[35] Y. Jin, L. Wang, G. Chen, X. Lin, W. Miao and Z. Fu, "Exposure of mice to atrazine and its metabolite diaminochlorotriazine elicits oxidative stress and endocrine disruption," Environ Toxicol Pharmacol, 37, 2014, pp. 782–90. doi: 10.1016/j. etap.2014.02.014

[36] E. R. Kabir, M. S. Rahman and I. Rahman, "A review on endocrine disruptors and their possible impacts on human health," Environ. Toxicol. Pharmacol., 40, 2015, pp. 241–258. doi: 10.1016/j.etap.2015.06.009

[37] A. Kamboj, R. Kiran and R. Sandhir, "Carbofuran-induced neurochemical and neurobehavioral alterations in rats: attenuation by N-acetylcysteine," Exp Brain Res., 170(4), 2006, pp. 567-575.

[38] S. Karami-Mohajeri and M. Abdollahi, "Toxic influence of organophosphate, carbamate, and organochlorine pesticides on cellular metabolism of lipids, proteins, and carbohydrates: a systematic review," Hum Exp Toxicol, 30(9), 2011, pp. 1119–1140. doi: 10.1177/ 0960327 110388959

[39] G. Kaushik, S. Satya and S. Naik, "Food processing a tool to pesticide residue dissipation–A review," Food Res. Int., 42, 2009, pp. 26–40. doi: 10.1016/ j.foodres. 2008. 09.009

[40] A. Kaviraj and A. Gupta, "Biomarkers of type II synthetic pyrethroid pesticides in freshwater fish," BioMed Research International, 2014, 928063. https://doi.org/ 10.1155/2014/928063.

[41] M. K. Kettles, S. R. Browning, T. S. Prince and S. W. Horstman, "Triazine herbicide exposure and breast cancer incidence: an ecologic study of Kentucky counties," Environ Health Perspect, 105, 1997, pp. 1222–1227. doi:10.1289/ehp.971051222

[42] M. J. Khan, M. S. Zia and M. Qasim, "Use of pesticides and their role in environmental pollution," World Acad. Sci. Eng. Technol., 72, 2010, pp. 122–128.

[43] N. Khatri and S. Tyagi, "Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas," Front. Life Sci., 8, 2015, pp. 23–39. doi: 10.1080/21553769.2014.933716

[44] J. H. Kolaczinski and C. F. Curtis, "Chronic illness as a result of low-level exposure to synthetic pyrethroid insecticides: a review of the debate," Food Chem Toxicol, 42, 2004, pp. 697–706. doi:10.1016/j.fct.2003.12.008

[45] M. Kwiatkowska, B. Huras and B. Bukowska, "The effect of metabolites and impurities of glyphosate on human erythrocytes (in vitro)," Pestic Biochem Physiol, 109, 2014, pp. 34–43. doi:10.1016/j.pestbp.2014.01.003

[46] D. Li, Q. Huang, M. Lu, L. Zhang, Z. Yang and M. Zong, "The organophosphate insecticide chlorpyrifos confers its genotoxic effects by inducing DNA damage and cell apoptosis," Chemosphere, 135, 2015, pp. 387–93. doi: 10.1016/j. chemosphere.2015.05.024

[47] J. N. Lin, C. L. Lin, M. C. Lin, C. H. Lai, H. H. Lin and C. H. Yang, "Increased risk of dementia in patients with acute organophosphate and carbamate poisoning: a nationwide population-based cohort study," Medicine (Baltimore), 94, 2015, pp. e1187. doi: 10.1097/ MD.0000000000001187

[48] Y. Liu, R. Mo, F. Tang, Y. Fu and Y. Guo, "Influence of different formulations on chlorpyrifos behavior and risk assessment in bamboo forest of China," Environ. Sci. Pol. Res., 22, 2015, pp. 20245–20254. doi: 10.1007/s11356-015-5272-2

[49] M. Margni, D. Rossier, P. Crettaz and O. Jolliet, "Life cycle impact assessment of pesticides on human health and ecosystems," Agric. Ecosyst Environ., 93, 2002, pp. 379–392. doi: 10.1016/S0167-8809(01)00336-X

[50] V. Mathur, P. J. John and I. Soni, "Blood levels of organochlorine pesticide residues and risk of reproductive tract cancer among women from Jaipur, India," Adv Exp Med Bio, 617, 2008, pp. 387-394.

[51] J. D. Meeker, D. B. Barr and R. Hauser, "Human semen quality and sperm DNA damage in relation to urinary metabolites of pyrethroid insecticides," Hum. Reprod., 23, 2008, pp. 1932–1940. doi:10.1093/humrep/den242

[52] A. Mieldazys, R. Mieldazys, G. Vilkevicius and A. Stulginskis, "Agriculture: Use of Pesticides/Plant Protection Products," Bilbao: EU-OSHA, 2015.

[53] W. Mnif, A. I. H. Hassine, A. Bouaziz, A. Bartegi, O. Thomas and B. Roig, "Effect of endocrine disruptor pesticides: a review," Int J Environ Res Public Health, 8, 2011, pp. 2265–2203. doi: 10.3390/ijerph8062265

[54] H. M. Mugo, "Studies of Insect Pests of Pigeonpea, Cajanus cajan (l) Millsp, During the Flowering and Post-Flowering Stages and their Impact on Seed Yield in Kenya," Kenya: University of Nairobi, 1998.

[55] H. Nozaki, N. Aikawa and Y. Shinozawa, Sarin poisoning on Tokyo subway. Lancet, 345(8955), 1995, pp. 980-981.

[56] S. Obiri, S. J. Cobbina, F. A. Armah and I. Luginaah, "Assessment of cancer and noncancer health risks from exposure to PAHs in street dust in the Tamale Metropolis, Ghana," J. Environ. Sci. Health Part A, 48, 2013, pp. 408–416. doi: 10.1080/ 10934529. 2013. 728914

[57] G. G. Pandit and S. K. Sahu, "Assessment of risk to public health posed by persistent organochlorine pesticide residues in milk and milk products in Mumbai, India," J Environ Monit, 4(1), 2002, pp. 182-185.

[58] A. K. Panigrahi, N. Choudhury and J. Tarafdar, "Pollutional impact of some selective agricultural pesticides on fish *Cyprinus carpio*," IMPACT, 2, 2014, pp. 71–76.

[59] V. J. Pereira, J. P. A. R. da Cunha, T. P. de Morais, J. P. Ribeiro-Oliveira and J. B. de Morais, "Physical-chemical properties of pesticides: concepts, applications, and interactions with the environment," Biosci. J., 32, 2016, pp. 627–641.

[60] M. Pirsaheb, M. Limoee, F. Namdari and R. Khamutian, "Organochlorine pesticides residue in breast milk: a systematic review," Med J Islam Repub Iran, 29, 2015, pp. 228.

[61] S. P. Proctor, K. J. Heaton and T. Heeren, "Effects of sarin and cyclosarin exposure during the 1991 Gulf War on neurobehavioral functioning in US army veterans," Neurotoxicology, 27(6), 2006, pp. 931-939.

[62] F. Qin, Y. X. Gao, B. Y. Guo, P. Xu, J. Z. Li and H. L. Wang, "Environmental behavior of benalaxyl and furalaxyl enantiomers in agricultural soils," J. Environ. Sci. Health Part B, 49, 2014, pp. 738–746. doi: 10.1080/ 03601234.2014.929482

[63] M. Radwan, J. Jurewicz, B. Wielgomas, M. Piskunowicz, W. Sobala and P. Radwan, "The association between environmental exposure to pyrethroids and sperm aneuploidy," Chemo, 128, 2015, pp. 42–48. doi: 10.1016/j.chemosphere.2014.12.077

[64] R. Rahimi, S. Nikfar and M. Abdollahi, "Increased morbidity and mortality in acute human

organophosphate-poisoned patients treated by oximes: a meta-analysis of clinical trials," Hum Exp Toxicol, 25(3), 2006, pp. 157-162.

[65] A. Ranjbar, H. Solhi and F. J. Mashayekhi, "Oxidative stress in acute human poisoning with organophosphorus insecticides; a case control study," Environ Toxicol Pharmacol., 20(1), 2005, pp. 88-91.

[66] V. A. Rauh, W. E. Garcia, R. M. Whyatt, M. K. Horton, D. B. Barr and E. D. Louis, "Prenatal exposure to the organophosphate pesticide chlorpyrifos and childhood tremor," Neurotoxicology, 51, 2015, pp. 80–86. doi:10.1016/j.neuro.2015.09.004

[67] H. Rehim, E. Hegazy and A. El-Barbary, "Radiation modification of natural polysaccharides for application in agriculture," Poly., 50, 2009, pp. 1952–1957.

[68] L. M. Rodríguez-Alcala, C. Sa, L. L. Pimentel, D. Pestana, D. Teixeira and A. Faria, "Endocrine disruptor DDE associated with a high-fat diet enhances the impairment of liver fatty acid composition in rats," J Agric Food Chem, 63, 2015, pp. 9341–9348. doi:10.1021/acs.jafc.5b03274

[69] A. M. Saillenfait, D. Ndiaye and J. P. Sabate, "Pyrethroids: exposure and health effects–an update," International Journal of Hygiene and Environmental Health, 218, 2015, pp. 281–292.

[70] A. Samsel and S. Seneff, "Glyphosate, pathways to modern diseases III: manganese, neurological diseases, and associated pathologies," Surg Neurol Int, 6, 2015, pp. 45. doi:10.4103/2152-7806.153876

[71] A. Samsel and S. Seneff, "Glyphosate, pathways to modern diseases II: celiac sprue and gluten intolerance," Interdiscip Toxicol, 6, 2013, pp. 159–84. doi: 10.2478/intox-2013-0026

[72] H. Schmutterer, "Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*," Ann Rev Entomol, 35, 1990, pp. 271- 297.

[73] P. Schreinemachers and P. Tipraqsa, "Agricultural pesticides and land use intensification in high, middle and low income countries," Food Pol, 37, 2012, pp. 616–626.doi:10.1016/j.foodpol.2012.06.003

[74] A. A. Sharbidre, V. Metkari and P. Ka Patode, "Effect of diazinon on acetylcholinesterase activity and lipid," Res. J. Environ. Toxicol. 5, 2011, pp. 152–161. doi: 10.3923/rject.2011.152.161

[75] I. Sharma, R. Bhardwaj and P. K. Pati, "Exogenous application of 28-homobrassinolide modulates the dynamics of salt and pesticides induced stress responses in an elite rice variety Pusa Basmati-1," J. Plant Growth Regul. 34, 2015, pp. 509–518.

[76] P. B. Singh, V. Singh and P. K. Nayak, "Pesticide residues and reproductive dysfunction in different vertebrates from north India," Food Chem Toxicol, 46(7), 2008, pp. 2533-2539.

[77] C. Smith-Spangler, M. L. Brandeau and G. E. Hunter, "Are organic foods safer or healthier than conventional alternatives? a systematic review," Ann Intern Med, 157(5), 2012, pp. 348-366.

[78] J. Socorro, A. Durand, B. Temime-Roussel, S. Gligorovski, H. Wortham and E. Quivet, "The persistence of pesticides in atmospheric particulate phase: An emerging air quality issue," Sci. Rep., 6, 2016, pp. 1–7. doi: 10.1038/srep33456

[79] D. W. Sparling, "Chapter 4 - Organochlorine Pesticides. In Ecotoxicology Essentials (San Diego: Academic Press)," 2016, pp. 69- 107. https://doi.org/ 10.1016/B978-0-12-801947-4.00004-4.

[80] K. Steffens, M. Larsbo, J. Moeys, N. Jarvis and E. Lewan, "Predicting pesticide leaching under climate change: Importance of model structure and parameter uncertainty," Agri. Ecol. Environ., 172, 2013, pp. 24–34. doi: 10.1016/j.agee.2013.03.018

[81] S. Stehle and R. Schulz, "Agricultural insecticides threaten surface waters at the global scale," Proc. Natl. Acad. Sci., 112, 2015, pp. 5750–5755. doi: 10.1073/pnas.1500232112

[82] N. L. Swanson, A. Leu, J. Abrahamson and B. Wallet, "Genetically engineered crops, glyphosate and the deterioration of health in the United States of America," J Org Syst, 9, 2014, pp. 6–37.

[83] S. Thongprakaisang, A. Thiantanawat, N. Rangkadilok, T. Suriyo and J. Satayavivad, "Glyphosate induces human breast cancer cells growth via estrogen receptors," Food Chem Toxicol, 59, 2013, pp. 129–36. doi: 10.1016/j.fct.2013.05.057

[84] V. Turusov, V. Rakitsky and L. Tomatis, "Dichlorodiphenyltrichloroethane (DDT): ubiquity, persistence, and risks," Environ Health Perspect, 110, 2002, pp. 125–8. doi:10.1289/ehp.02110125

[85] S. Ullah, Z. Hasan, A. Zuberi, N. Younus and S. Rauf, "Comparative study on body composition of two chinese carps, common carp (*Cyprinus carpio*) and silver carp (*Hypophthalmichthys molitrix*)," Glob. Vet., 13, 2014, pp. 867–876. doi: 10.5829/idosi.gv.2014.13.05.86234

[86] J. Unsworth, "History of pesticide use," International Union of pure and applied chemistry (IUPAC). North Carolina: IUPAC, 2010.

[87] B. L. Waddell, S. H. Zahm, D. Baris, D.D. Weisenburger, F. Holmes and L. F. Burmeister, "Agricultural use of organophosphate pesticides and the risk of non-Hodgkin's lymphoma among male farmers (United States)," Cancer Causes Control, 12, 2001, pp. 509–17. doi: 10.1023/A: 1011293208949

[88] World Health Organization, "International Code of Conduct on Pesticide Management: Guidelines on Pesticide Legislation," Geneva: World Health Organization, 2015.

[89] X. J. Xia, Y. Y. Huang, L. Wang, L. F. Huang, Y. L. Yu and Y. H. Zhou, Pesticides-induced depression of photo synthesis was alleviated by 24-epibrassinolide pre-treatment in *Cucumis sativus* L. Pest. Biochem Phys., 86, 2006, pp. 42–48. doi: 10.1016/j.pestbp. 2006. 01.005

[90] I. C. Yadav, N. L. Devi, J. H. Syed, Z. Cheng, J. Li and G. Zhang, "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, 2015, pp. 123–137. doi: 10.1016/j.scitotenv.2014.12.041

[91] T. Zheng, S. H. Zahm, K. P. Cantor, D. D. Weisenburger, Y. Zhang and A. Blair, Agricultural exposure to carbamate pesticides and risk of non-hodgkin lymphoma. J Occup Environ Med, 43, 2001, pp. 641–649. doi: 10.1097/ 00043764-200107000-00012

BIOGRAPHIES

An academic professional with 18 years of teaching experience in undergraduate level. Possesses an analytical mind coupled with good verbal and written communication skills. An active researcher who has published papers in peer reviewed academic journals and has a direct role in management of an institution. Special interests and areas of research include Entomo- logy and Environmental Biology.