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Review Article

Review of the correlation between pesticide uses and human chronic diseases

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ABSTRACT: A pest is every living thing, that has a detrimental effect on people or their interests. They can transmit diseases, harm crops, and interfere with daily activities. Pests like rats and insects are often found in human environments. Pesticides are biological or chemical substances designed to resist, attract, control, or prevent any biological entity that is deemed a pest. Pesticides have various advantages but are also associated with several environmental and public health challenges. The review thoroughly analyzes the body of research on pesticide usage, including its categorization, historical background, impacts on human health as well as how they affect surroundings and also capture the resistance development. Understanding the link between pesticide usage and chronic diseases including Parkinson's disease, diabetes, cancer, and neurological problems is necessary to develop practical strategies for reducing these chronic diseases. The review examines the correlation between exposure to pesticides and chronic diseases and management exposure reduction techniques which include integrated pest management, sustainable agriculture, stringent pesticide regulation, public awareness campaigns, and the right use of personal protective are techniques discussed. Implementing these techniques would drastically mitigate the adverse effects of chronic diseases among people while ensuring the use of pesticides.

Keywords: Chronic diseases, environmental impact, human health, pesticides, pests.

INTRODUCTION

A pest is every living thing, that has a detrimental effect on people or their interests. They can transmit illness, harm crops, and interfere with daily routines. Although the definition of a pest varies widely among individuals, in general, anything is labeled a pest because of its negative impacts (Got Pests, 2022). Pests are defined as "plague or devastating infectious disease" in Latin, from whence the English word "pest" is derived (Mishra *et al*., 2023). The Latin word "**to *kill***" is where the name "-***cide***" originates (National Pesticides Information Center, 2023). Pesticides are biological or chemical substances designed to resist, attract, control, or prevent any biological entity that is deemed a pest (Abubakar *et al.,* 2020; Science, 2013). Pesticides have been identified to be one of the primary causes of environmental pollution that exists in the modern world (Mostafalou and Abdollahi, 2013). Pesticides are commonly used in agricultural production to reduce insect infestations, protect crops from yield losses, and improve product quality. They ensure farmers' profits, provide consistent food at affordable prices, and enhance aesthetic appeal (Damalas, 2009). Pesticides are described as compounds that are used in residential and agricultural settings to eliminate, repel, or control animal and plant life that is considered to cause damage or be an annoyance (National Institute of Environmental Health Sciences, 2023; Cooper and Dobson, 2007). There are over 800 pesticides registered for use in the United States, some of which are used in large quantities and may pose risks for a variety of health problems (Schwingl *et al*., 2021). Pesticide exposures constitute a more serious health threat than recognized because many cases of poisoning go unreported. Pesticides are commonly used in the farming sector to protect plants from insects and increase output (Environmental Factor, 2022). Pesticides are used to eradicate insects and other pests that attack and damage crops (Pimentel *et al.*, 1992; National Library of Medicine, 1993). For generations, farmers have employed various insecticides to safeguard their crops. Although pesticides are beneficial to crops, they have a detrimental effect on the ecosystem (Edwards, 1993). The devastation of biodiversity might result from the overuse of pesticides. Hazardous pesticides threaten the survival of many animals, birds, and aquatic life. A substance or mixture used to get rid of or manage pests is considered a pesticide by the Food and Agriculture Organization (FAO). Insects, animals, plants, and microbes that are harmful to humans, cattle, or crops can all be considered pests (BYJU'S, 2019). Throughout the food production process, from planting to storage, pesticides are used to prevent damage and loss.

History of pesticides

Humanity has continued to be utilizing pesticides for centuries. The use of these compounds extends back to the ninth century BC when Homeric poets mentioned using fungicides (National Library of Medicine, 1993). Many concoctions have been created since then to manage weeds, insects, fungi, and other pests. The possibility of long-term toxicity and bioaccumulation of chlorinated hydrocarbons was first identified in the late 1960s. During the era of the Bible through the 1950s, the most common insecticides were organic compounds and herb extracts (Sparks and Bryant, 2021; Umetsu and Shirai, 2020). The inorganic compounds comprised derivatives of copper, arsenic, mercury, sulfur, and other elements, while the plant extracts contained pyrethrum, nicotine, and rotenone, among other things. While employing the least dangerous of these organic farming (Food and Agricultural Organisation of the United Nations, 2023) in the 1940s, the insecticide DDT and the herbicide 2,4-D were initially commercially accessible (Sparks and Bryant, 2021). These man-made organic (as opposed to inorganic) substances were very profitable and widely used. The pesticide business grew as a result of the plethora of other synthetic pesticides that were introduced in the 1950s and 1960s (Sparks and Lorsbach, 2023; EFSA *et al.,* 2023). This period saw the growing realization that DDT, which had been widely sprayed in the environment to kill the vector, had built up in the food chain and turned into a global pollutant, as described in the well-known book Silent Spring. Eventually, all persistent pesticides were outlawed globally for vector control (Umetsu and Shirai, 2020). There is also a brief assessment of studies on pesticide development and global pesticide sales (Sugimura *et al*., 1995).

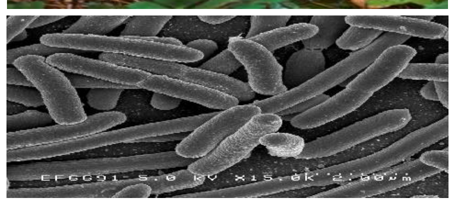
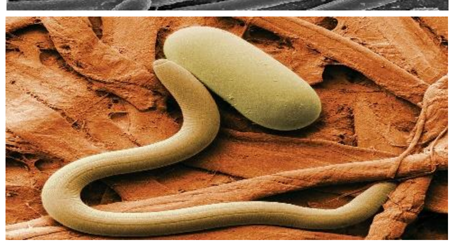
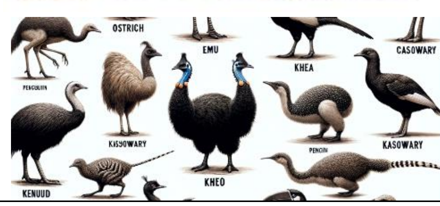
Pesticides are chemical or biological substances designed to control specific pests

There is a plethora of pesticides available, many of which target different species. Algaecides, for instance, restrict algae (Gupta and Crissman, 2013); fungicides fight fungal infections (Fernández-Quiroz *et al.,* 2023; Cleveland Clinic, 2024); insecticides go after insects, and herbicides get rid of undesirable plants. Molluscicides for snails and slugs, rodenticides for rats, and miticides for mites are some more kinds (Table 1). While organic pesticides are a subset allowed in organic agriculture, biopesticides use natural materials or organisms to treat pests. Pesticides also include insect growth regulators, disinfectants and antimicrobials to kill pathogens, defoliants to remove leaves from plants, and desiccants to dry them out. Additional specialized pesticides include ovicides, which kill insect eggs, repellents, which discourage pests, plant growth regulators, which alter plant development, and synergists, which increase the effectiveness of pesticides. In some stages or applications, treated seeds and wood preservatives protect against pests. Pests have an impulse to become resistant to insecticides.

Advantages of pesticides

Pesticides are essential to the development of agricultural products. Due to their significant advantages in agricultural produce, farmers are utilizing them to manage weeds and insects (Tudi *et al.*, 2021; Lengai and Muthomi, 2018). The use of pesticides increases agricultural yields, advances crop protection technology, decreases food prices, and improves food quality and quantity (Stoytcheva, 2011; Pesticides Facts, n.d). It also affects food costs. Pesticides are the best way to get rid of insects that spread diseases including dengue fever, malaria, Lyme disease, and the West vile virus. They also help safeguard human health from fungi and insects (Ahmad *et al*., 2024). Pesticides are

Table 1. Pesticides classification depends on the type of organisms they aim to prevent (Source: United Nations, 2021; Fourdinier, 2017).

Pesticides	**Images**	**Pest Targeted**
Herbicides		Weeds, algae
Insecticides		Insects
Acaricide		Mites
Fungicide		
Bactericide		Bacteria
Nematicide		Nematodes
Molluscicide		Snails, molluscs
Avicide		Birds

necessary for increased food safety, human health, longevity, and quality of life as well as for lowering energy use, environmental damage, and drudgery (Cooper and Dobson, 2007). Pesticides have several benefits, some of which are as follows: With pesticides, farmers can produce more on less land. Ample harvests are guaranteed by pesticides. Pesticides keep food costs down. Pesticides aid in the reduction of illnesses spread by insects and water. Environmental preservation is aided by pesticides. The struggle of manual weeding has been eliminated by herbicides, and pesticides have turned emerging nations become food producers, keeping items in storage safe (Crop Life India, 2017).

PESTICIDES AND HUMAN HEALTH

Presently a lot of pesticides are utilized in the food production process (Tudi *et al*., 2021; Fenik *et al*., 2011). Pesticides are used by farmers to control weed growth and protect from insect, rodent, and mould damage to crops. They are used to improve storage life and stop spoiling after harvest. Animal farms may also utilize pesticides to manage insect problems. Pesticide residues are tiny amounts of pesticides that occasionally stay in or on foods after being applied in these ways (Inobeme *et al*., 2023). Pesticide residues have been connected to several illnesses and problems, raising concerns for public health. Pesticide residues are always present in the environment, polluting soil, water, and food and endangering human health through both short and long-term exposure (Ahmad *et al.,* 2024). Inhaling, consuming, or coming into touch with a high dosage of pesticides can result in acute toxicity; repeated or extended exposure to pesticides results in long-term toxicity (Singh *et al.,* 2020). Pesticides can bring multiple contaminants, including insulin difficulties, brain damage, genetic mutation, cancer risk, and teratogenicity (Fang *et al*., 2020). Research estimates that 3 million people were poisoned and 200,000 people died globally as a result of pesticide exposure, with poorer nations accounting for the majority of these deaths (Boedeker *et al*., 2020).

Correlation between pesticide exposure and chronic diseases

As pesticides are widely used worldwide, fears surrounding their potential impact on human health are intensifying. Numerous studies have demonstrated an affiliation between pesticide exposure and a higher chance of developing chronic diseases, such as diabetes, different cancers, ALS, Alzheimer's disease, and Parkinson's, and abnormalities in pregnancy (Mostafalou and Abdollahi, 2013). Leukaemia and non-Hodgkin lymphoma are positively connected with pesticide exposure; dose-response relationships have been shown, and specific pesticides are implicated. Pregnant women, parents at work, and children are also associated with cancer (Landis *et al*., 1998). The most significant associations are found in prostate and brain cancer, but parental pesticide exposure is associated with kidney cancer in offspring (Bassil *et al*., 2007).

Pesticides causes cancer

Women who handle pesticides have a greater risk of developing ovary cancer; farmers and pesticide applicators have higher prostate cancer rates; crop-dusters and farm wives have a greater likelihood of skin cancer; and so on (Pest Action Network, n.d). According to research published in the International Journal of Hygiene and Environmental Health, children who are exposed to chemicals such as bromacil and acephate are more likely to develop unilateral retinoblastoma, which is one of the most common pediatric cancers and prostate cancer (Heck, 2022; Band *et al*., 2011). A significant surge of research investigating the potential association between pesticides and cancer has occurred in the last 10 years (Pedroso *et al.,* 2022; Lynge and Anttila, 1997). These studies have mostly been conducted in the United States of America France, India, Brazil, and seventeen other countries. The Global Institute for Cancer Research has identified pesticides and chemicals containing arsenic as carcinogenic in humans (Zahm *et al*., 1997). Phenoxy acid pesticides or contaminants have been scientifically connected with malignant lymphoma and tumours of soft tissue (STS), according to epidemiologic studies, which have occasionally produced contradictory results (Ahlborg *et al*., 1995). Organochlorine insecticides have been associated less frequently with lung and breast cancers, STS, which are cancer of the blood, NHL, and lymphoma of the non-Hodgkin's (Blair *et al*., 1985).

Neurodegenerative diseases

Neurodegenerative diseases are a broad category of illnesses caused by the gradual destruction of the nerve system's cells and connections, which are vital for sensation, movement, strength, coordination, and thought processes (O'Donnel, 2024). Pesticides like dieldrin, rotenone, and paraquat cause dopaminergic neurons to undergo apoptosis, which changes how these neurons function in the brain and results in neurological diseases such as disease and/or dementia (Yu *et al*., 2021; Chin-Chan *et al*., 2015). Neurodegenerative illnesses and pesticide exposure. Organochlorine pesticide toxicity may be connected to chronic motor neuron disease (McBurney, 2017). Type 2 diabetes and other environmental variables are nearly invariably associated. Glyphosate (GLY) is a common herbicide that may have negative health consequences on the general public, including the possibility of diabetes (Owens *et al*., 2010). Information on the relationship between 9 distinct health outcomes, including type 2 diabetes and the quantity of GLY in urine (T2DM).

Diabetes

Diabetes and pesticide exposure, investigating data from epidemiological studies, *vitro* and *in vivo* studies, and the effects of pesticides on people and the environment that induce diabetes (Diabetes and the Environment, n.d.; Wei *et al*., 2023). The gut microbiota is impacted by glyphosate and roundup, and this has been connected to diabetes (Walsh *et al*., 2023; Chen *et al*., 2024). According to a study and meta-analysis, organophosphate insecticides were linked to a higher risk of developing diabetes (Zhao *et al*., 2023; Shapiro *et al*., 2016). "A higher risk of obesity and type 2 diabetes is associated with exposure to pesticides," based on an analysis of the data from laboratories and humans (Xiao *et al*., 2017; Simões-Wüst *et al*., 2017). Type 2 diabetes and obesity are metabolic disorders associated with exposure to organophosphorus pesticides, and early life exposure to these pesticides may be crucial for these outcomes (Czajka *et al*., 2019). Farmers in Greece have had incidences of type 2 diabetes after using sulfonylureas as a pesticide for decades (Kampouraki *et al*., 2023; Simões-Wüst *et al*., 2017; Kaur *et al*., 2020). In China, high levels of pyrethroid insecticides have been associated with a higher risk of developing type 2 diabetes, mostly as a result of the pesticide (Jia *et al.,* 2023; Jia *et al.,* 2022; Saldana *et al.,* 2007).

The Parkinson's disease

Parkinson’s disease (PD) is being investigated and shown to the caused by environmental factors. One of the main groups of environmental factors linked to Parkinson's disease is pesticides (Hatcher *et al*., 2008; Moura *et al.,* 2023). The evidence about each of the main pesticide subclasses' capacity to increase the occurrence of Parkinson's disease was scrutinized (Hancock *et al.,* 2008). This study revealed that the possibility of developing Parkinson's disease (PD) is twice as high for people who are highly exposed to household insecticides (Brown *et al*., 2006; Dhillon *et al*., 2008). Pesticide exposure and the Parkinson's disease are linked. Parkinson's disease (PD) can result from the inhaling of pesticides (Dick, 2006; Rugbjerg *et al.,* 2011). The risk components of Parkinson's disease are frequently mentioned including pesticide use and associated lifestyle choices (such as farming and well-water exposure).

Environmental effects of pesticides

The stability of the world system and the sustainability of the environment are both threatened by pesticides. Pesticide misuse leads to pollution and pesticides' long-term effects on the environment Dick, 2006; Rugbjerg *et al*., 2011). Pesticides can contaminate other plants, soil, grass, and groundwater. In addition to weeds and insects, pesticides are also damaging a wide range of other animals, including fish, birds, beneficial insects, and non-target plants (Aktar *et al*., 2009). The herbicides can also be harmful, although insecticides often pose the most immediate threat to non-target species. Pesticides can pollute flora, the soil, grass, and drainage (Tudi *et al*., 2021; Pesticide Action Network UK, 2017. Pesticides have negative effects beyond their application location, such as runoff, drift, and improper manufacturing, transportation, storage, and disposal methods. Using pesticides often can lead to resistance building and even a return of the pest (Rajak *et al*., 2023). Alternatives like integrated pest control and sustainable agricultural methods like polyculture can lessen these effects without the use of hazardous or toxic chemicals.

Preventing and mitigating strategies for pesticide exposure

The environment and public health may be greatly protected against pesticide exposure by putting into practice a multimodal strategy that includes integrated pest management, sustainable agriculture, stringent pesticide regulation, public awareness campaigns, and employing personal protective equipment (PPE) effectively (Ahmad *et al*., 2024).

Integrated pest management

Integrated pest management (IPM) provides a thorough and sustainable solution to the numerous issues that weeds, plant diseases, and insect pests in agriculture bring (Nalage *et al*., 2023). Integrated Pest Management is a flexible approach that reduces risks to the environment and public health by taking into account all available pest management techniques and protocols. It uses a combination of chemical, biological, and cultural techniques to control weeds, insects, and illnesses (Crop Life International, 2014). It assesses local control strategies and techniques while taking cost-effectiveness into account. Adaptable, IPM leverages current research, technology, expertise, and experience together with regional resources. Instead of having strict or unbending standards, it takes a flexible approach that makes good use of available resources locally. IPM is a method of choice that aids in the prevention of pest-related problems (Applicator Core, n.d). IPM programs take into consideration all available data and remedies to effectively manage pests. An option to completely avoid or significantly limit the use of pesticides as well as reduce the toxicity and exposure to any chemicals used is provided by IPM, or integrated pest management, is a proactive, surveillance, and management program. IPM addresses a broad spectrum of pest problems by employing a variety of techniques and methods, including cultural, biological, and structural approaches (Beyond Pesticides, n.d).

Sustainable agriculture

A sustainable agribusiness yields massive quantities of food without contaminating the environment or depleting the resources of the earth (Earles and Williams, 2005). A successful sustainable agriculture is intrinsically linked to thriving rural communities, successful farming families, and access to healthy food for all. Sustainable agriculture is also the agriculture of ethical principles. A farm is regarded to be implementing sustainable agriculture if it can produce food continually without significantly affecting the health of the environment (SAREP, n.d). Deforestation, soil degradation, biodiversity loss, irrigation problems, pollution, and other challenges may all be addressed using sustainable agriculture (Coulibaly *et al.,* 2021; Horn *et al.,* 2019). Sustainable agriculture is an environmentally beneficial management strategy, according to Hobbs *et al.* (2008).

Pesticide regulation and monitoring

Preventing long-term diseases by reducing chemical exposure necessitates pesticide governance and management. The risk of chronic diseases including cancer, respiratory diseases, and neurological problems decreases when there are effective laws and strict monitoring in place to reduce pesticide residues in food (McEachran *et al*., 2015; Rodríguez-Gómez et al., 2020; Wigenstam *et al*., 2021). To safeguard public health and create a safer environment, it is imperative to enforce safety regulations and encourage comprehensive monitoring procedures (Cupp *et al*., 2020; Areo *et al*., 2022; Pinkert and Zeuss, 2018; Arunrat *et al.,* 2022).

Public awareness campaigns

Farmers' health can be safeguarded from pesticide risks by gaining education and training (Ahmadipour and Nakhei, 2024). Protecting farmers' health requires educating them about the usage of pesticides. Risks including cancer, skin conditions, and respiratory problems can be reduced with the right training (Asghar et al., 2016; Oluwole and Cheke, 2009). Programs that are effective instruct participants on safe handling, spraying methods, and PPE use. Understanding pesticide labels and investigating substitutes like integrated pest control are also included in training (Khalil et al., 2021; Ahmadipour and Nakhei, 2024). Research shows that this kind of instruction lessens health issues associated with pesticides (Jenkins and Rodgers, 2020; Rattanawitoon *et al*., 2023) Consequently, funding farmer education encourages safer methods and improved health results.

Personal protective equipment

Farmers are required to wear the proper personal protective equipment (PPE) throughout every step of pesticide treatment to mitigate the health risks related to handling pesticides. PPE is not used by farmers, however, according to studies and empirical evidence, before, during, and following pesticide application (Yarpuz-Bozdogan, 2018). As a result, pesticide poisoning, both acute and chronic, can frequently affect farmers. While many intoxications may result from hazardous agricultural methods and excessive pesticide application, personal protective equipment (PPE) plays a crucial role in minimizing the toxicological consequences of contact with pesticides (Lari *et al*., 2023). When it comes to safety initiatives, personal protective equipment (PPE) is vital; in numerous countries, obtaining authorization requires providing the use of PPE (Garrigou *et al*., 2020). Therefore, one way to decrease pesticide exposure to the skin is to wear the proper personal protection equipment when applying pesticides (Naksata *et al*., 2020).

CONCLUSION

Implementing a comprehensive strategy is crucial for reducing the harmful effects of pesticide use on the environment and public health. Developing sustainable agricultural methods, enforcing pesticide regulations and laws, encouraging integrated pest management, increasing public awareness, and making sure personal protective equipment is worn appropriately are all examples of this. We can maintain agricultural productivity while also protecting human well-being and the health of the environment by adopting these measures.

Recommendation

It is recommended that governments and agricultural firms adopt sustainable agriculture methods and biopesticides to lessen dependency on chemicals to address the challenges regarding the application of pesticides. It is essential to improve Integrated Pest Management (IPM) and examine the long-term implications. It will also be vital to maximize personal protective equipment (PPE), raise public awareness, and improve pesticide rules and enforcement. Effective solutions will be aided by ongoing research into the detrimental effects of pesticides, particularly their connections to chronic diseases. By reducing pesticide-related effects, these measures will safeguard the environment and public health. Future studies should concentrate on creating innovative and lasting methods for controlling pests along with investigating the long-term effects of pesticide use on the environment and public health.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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