www.envsciarch.com
ENVIRONMENTAL SCIENCE ARCHIVES
ISSN: 2583-5092
Volume IV Issue 2, 2025

Received: 2025/11/12
Accepted: 2025/12/17
Published: 2025/12/19

RESEARCH PAPER | OPEN ACCESS

Pesticides and Neurotoxicity in Aquatic, Terrestrial Animals and Humans: A Review

OP Bansal*
Department of Chemistry, DS College, Aligarh, India - 202001
*Correspondence for materials should be addressed to OPB (email: drop1955@gmail.com)

Abstract
To feed the growing global population, agricultural production must continuously increase. The use of pesticides has been a major contributor to increased crop yields. However, their indiscriminate and widespread application has led to serious health concerns for non-target aquatic organisms, wild animals, and humans. Pesticides can enter the body through ingestion, inhalation, dermal absorption, or ocular exposure. Research findings indicate that, in addition to organochlorine, organophosphate, and carbamate pesticides, newly introduced pyrethroids also exert significant adverse effects on the nervous system of aquatic organisms, wildlife, and humans. Impairment of neurological functions can result in dizziness, headaches, developmental delays in children, short- or long-term memory loss, and neurodegenerative disorders such as Alzheimer's and Parkinson's disease. Scientific studies have demonstrated that pesticide exposure triggers oxidative stress and disrupts neurotransmission in humans, animals, and aquatic organisms. These disruptions may cause neuronal damage, altered brain development, and neurodegenerative outcomes. In humans and animals, neurotoxicity is often associated with the inhibition of acetylcholinesterase (AChE), an enzyme essential for the breakdown of acetylcholine, a key neurotransmitter. Furthermore, certain pesticides inhibit mitochondrial complex I, leading to brain DNA damage. This review aims to present recent scientific evidence on the neurotoxic effects of pesticide exposure in aquatic organisms, animals, and humans.

Keywords: Pesticides; Neurotoxicity; Humans; Animals; Aquatic organisms

Introduction
The United Nations Food and Agriculture Organization (FAO) has defined a pesticide as any chemical compound or mixture of compounds (natural or synthetic) that can control, repel, prevent, or eradicate undesirable organisms such as insects, weeds, fungi, rodents, nematodes, and animal or human disease vectors (Pathak et al., 2022). Similarly, the United States Code of Federal Regulations defines pesticides as substances that act as plant regulators, desiccants, or defoliants (USEPA, 2023). After the Second World War, the use of synthetic pesticides significantly reduced agricultural losses and improved both the yield and quality of food at affordable levels (Khan et al., 2023; Tudi et al., 2021). The introduction of these compounds has played a major role in advancing global agriculture, particularly over the past century (Singh, 2025; Sidhu and Singh, 2025; Das et al., 2024; Bhatt et al., 2024; Mehra and Chadha, 2023; Kaushal and Singh, 2022; Tudi et al., 2021). Global pesticide production and usage increased from 0.2 million tons in the 1950s to 4.32 million tons in 2024 and is projected to reach 4.41 million tons by 2027.

The global pesticide market was valued at 126.5 billion USD in 2024 and is expected to grow to 181.6 billion USD by 2030, with an annual growth rate of 6.2%. Despite these agricultural benefits, pesticide exposure remains a major public health concern. Literature indicates that more than 40% of the global farming population, approximately 500 million people, experience pesticide poisoning annually (Garud et al., 2024). Alarmingly, only about 1% of the pesticides applied reach the intended target organisms, while the remaining 99% disperse into the environment, contaminating soil, air, water, and non-target organisms (Chen et al., 2025). This leads to environmental pollution, reduced crop quality, and harmful effects on aquatic organisms, terrestrial wildlife, and human health.

According to a joint WHO and UNEP report, pesticide exposure and the consumption of contaminated food contribute to around 200,000 deaths globally each year, with the majority occurring in developing countries (Ahmad et al., 2024).

Historical evidence further highlights the risks. Friedman et al. (2022) reported that more than 40,000 military personnel were affected by exposure to organophosphate and carbamate pesticides during the Gulf War. Mechanistically, pesticides in the human or animal body not only inhibit the activity of acetylcholinesterase but also generate reactive oxygen species (ROS). This oxidative stress disrupts antioxidant defenses, leading to cellular oxidative damage. Over the past 70 years, the misuse of pesticides has led to widespread accumulation of these toxicants in soil, water, air, and food.

Exposure to pesticide-contaminated environments or consumption of contaminated food and water has been strongly associated with chronic diseases including multiple cancers (brain, breast, prostate, bladder, and colon) (Gerken et al., 2024; Kim et al., 2022; Matich et al., 2021), neurological toxicity, Alzheimer's disease (AD) (Flores-Gutierrez et al., 2023; Frisoni et al., 2022), Parkinson's disease (Perrin et al., 2021), infertility (Somé et al., 2022; Fucic et al., 2021), leukemia (Nguyen et al., 2023; Rafeeinia et al., 2022; Foucault et al., 2021), and diabetes (Hern´andez-Mariano et al., 2022). Growing concerns over neurological disorders, manifesting as headaches, weakness or numbness in limbs, vision loss, reproductive issues, depression, cardiovascular problems, and influenza-like symptoms have stimulated extensive research over the past 15 years (Hirano et al., 2021). These nervous system impairments are often linked to oxidative stress, neuroinflammation, and neurodegeneration (Bartholomew et al., 2024; Song et al., 2023; Sidthilaw et al., 2022). Recent experimental studies (Ocmen et al., 2023; Pandey et al., 2023; Nuryati et al., 2022) have demonstrated that pesticide-induced neurotoxicity in both animals and humans may be mediated through mitochondrial dysfunction and oxidative stress across various cell types. Collectively, the evidence indicates that mitochondrial impairment and ROS generation represent central mechanisms underlying pesticide-induced toxicity and its associated health impacts.

This review provides a detailed classification of pesticides, their routes of entry into aquatic organisms, terrestrial animals, and humans, as well as the neurotoxic effects they induce across these groups. The findings of this review may assist healthcare professionals in developing strategies to minimize the neurotoxic impacts of pesticides in these populations.

Classification of the Pesticides

Pesticides are classified in several ways, viz., on the basis of source, chemical composition, on the basis of their modes of entry, on the basis of target pests and on the basis of toxicity.
Pesticides, on the basis of their source, are classified into natural and synthetic.

Natural pesticides

These are either plant-derived or mineral oil-based (also called biopesticides). The common examples of plant-based pesticides are Pyrethrins I and II, Ryania, Nicotine, Pyrethrum, Eugenol, Rotenone, etc. Pyrethrins are extracted from the plant *Chrysanthemum cineraria folium*. Pyrethrins, the esters of 3-phenoxy phenyl alcohol, are water-insoluble and fat-soluble. These compounds are less toxic to mammals and exist in Cis and Trans forms. These pesticides affect the muscular system of the pest and affect the sodium channel in the target.

Synthetic Pesticides

These are pesticides that are synthesized in the laboratory. These pesticides may be (i) Inorganic (Copper sulphate, Copper lime, sulphur, ferrous sulphate) and (ii) organic. Most commonly used pesticides are mostly organic.

Based on their chemical composition

Organochlorines, organophosphates, carbamates, Pyrethroids, and neonicotinoids are the main classes of pesticides based on their chemical composition.

Organochlorine pesticides (OCs)

Organochlorine pesticides or Chlorohydrocarbon pesticides belong to the first synthetic pesticide group. These pesticides have a cyclodiene ring with five or more chlorine atoms. These pesticides are widely used to control insects in the agriculture sector and for public health purposes to control vector-borne diseases like malaria, dengue, etc. DDT, DDD, DDE, BHC, aldrin, dieldrin, endosulfan, heptachlor, dicofol, chlordane, and methoxychlor are some of the most commonly used organochlorine pesticides. Due to their persistence in the environment and toxicity to non-target organisms, most of the pesticides of this class are banned. DDT is most commonly used as an OC because it is stored in the fat of humans/animals and is still found in the body of every living organism on Earth.

Organophosphate pesticides (OPs)

Organophosphorus pesticides are the esters, amides, or thiol derivatives of phosphoric acid, were first synthesized in 1937 as an alternative to OCs, as these broad-spectrum pesticides can be easily biodegraded. Based on the organic moiety present OPs are divided into three (i) Aliphatic: i.e. with phosphoric acid aliphatic chain/group is attached widely used are Malathion, Dichlorvos, Phorate (ii) aromatic: contains benzene ring with phosphoric acid, Carbofuran, Fenthion, Parathion are commonly used pesticides of this group, and (iii) heterocyclics: Heterocyclic ring (s) are attached with phosphoric acid moiety, Diazinon, Phosalone are members of this group. The organophosphate pesticides, excluding aromatic and sulphur-containing ones, can be easily degraded in the environment. Trichlorfan, Ronnel, Parathion, Malathion, Diazinon, dimethoate, carbofuran, chlorpyrifos, dichlorvos, fenthion, and glyphosphate are the most widely applied organophosphate pesticides. Organophosphate pesticides exert their toxic effects primarily by inhibiting acetylcholinesterase activity. These pesticides in humans and other terrestrial animals cause neurotoxic effects. Exposure for a long period enhances the probability of Parkinson's disease in humans (Garud et al., 2024).

Carbamate and Dithiocarbamate pesticides

Carbamate pesticides are broad-spectrum, easily degradable, fat-soluble pesticides, derivatives of carbamic acid (NH_2COOH) with a general molecular formula $R_2N{-}C(=O){-}OR'$ (where R is alcohol, oxime, or phenol and R' is ether, H, or alkyl group). These pesticides are toxic to those pests that have attained immunity against organochlorine and organophosphorus pesticides (Moreira et al., 2022). Pesticides of this class inhibit the secretion of nerve signal transmission enzyme acetylcholinesterase in pests as well as non-target organisms. Dimetan was the first synthetic pesticide of the carbamate class. Pesticides of this class are water-soluble and cannot be easily vaporized. Widely used carbamate pesticides are aldicarb, aminocarb, carbaryl, carbofuran, methomyl, oxamyl, and propoxur.

Dithiocarbamate pesticides, which were first synthesized after the Second World War, are broad-spectrum organosulfur compounds with chemical structure (R, R')N-(C=S)-SX, where R, R' can be an alkyl, alkenyl, aryl, or similar other groups, and X a metal ion. The review of data denotes that 21 compounds of this class are used as agro pesticides. These compounds are prepared by the reaction of carbon disulfide with a primary or secondary amine in a basic medium. Pesticides of this class bind thiol group(s) in enzymes and hinder the normal essential metabolic activities. Based on the carbon skeleton, the dithiocarbamates are classified into: (I) Methyl-dithiocarbamates (MDTCs), e.g., metam sodium; (II) Dimethyl-dithiocarbamates (DMDTCs), examples are ziram, thiram, and ferbam; (III) Ethylene-bis-dithiocarbamates (EBDTCs), widely used are mancozeb, maneb, zineb, and metiram; and (IV) Propylene-bis-dithiocarbamates (PBDTCs), i.e., propineb.

Pyrethroid pesticides

The pyrethroid pesticides that are synthetic water-insoluble and fat-soluble chemical compounds exist in Cis and Trans forms are the esters of 3-phenoxy phenyl alcohol. These compounds which are mainly used as insecticides are more toxic to insects, but toxicity to humans is very low. In 1949, the first pyrethroid pesticide, allethrin, was synthesized. The pesticides of this class affect the sodium channel of the pest, which results in nerve impulses and paralysis. The pyrethroids are divided into two groups: i) containing cyano radical, widely used are Cyphenothrin, Cypermethrin, Deltamethrin, fenvalerate, and ii) without cyano radical, viz., permethrin, tetramethrin.

Neonicotinoids

In 1990, the imidacloprid (IMI), a pesticide of the neonicotinoid class that is chemically related to nicotine, also known as neuro-active insecticides, was first marketed by Bayer Crop-Science. After 1995, due to their mode of selection and higher efficacy, neonicotinoid pesticides are the most widely used insecticides worldwide (Ferrari and Speltini, 2023; Casillas et al., 2022). These pesticides in insects bind to nicotinic acetylcholine receptors and adversely impact the nervous system of the insect. These pesticides are less toxic to non-target organisms (Chen et al., 2025).

Based on their target pests

Pesticides on the basis of target pests are classified as:

Insecticides

Insecticides are the chemical compounds that are used to control insect pests that damage crops in the field and storage facilities, and to control insect vectors that cause public health diseases like malaria, dengue, and Lyme. Worldwide, about one million insect species are known, of which approximately 10,000 are crop-harming insects. Literature survey has denoted that out of 10,000 species, 700 are responsible for major damages to crops in the field and storage facilities and to spread public health diseases like malaria, dengue, and Lyme (Garud et al., 2024; Hashimi et al., 2020). Insecticides either disturb the growth and development of pests or directly kill them. Most of the insecticides are neurotoxic and impact the nervous system of target and non-target organisms (Wan et al., 2025). Depending on the exposure time and dosage, insecticides affect the central nervous system, cardiovascular system, skeletal system, respiratory system, reproductive system, endocrine system, and skin in humans and wildlife animals (Shekhar et al., 2024; Rani et al., 2021). Organochlorine compounds, organophosphates, Carbamates, pyrethroids, and neonicotinoids are globally applied insecticides.

Herbicides or weedicides

These are chemicals that are used to control the growth of unwanted plants. The potential loss caused by herbicides in India is more than one-third of the total annual agricultural loss. These compounds kill weed plants either by contact or by retarding the metabolic activities of herbs (retards photosynthesis, amino acid production, pheromone production, and cell division) after sorption (Clabo et al., 2021). Selective herbicides target only weeds, leaving desired crops, while non-selective herbicides destroy all the plants of the applied field (Mohd-Ghazi et al., 2023; Montull and Torra, 2023). Most commonly used herbicides are Acetochlor, atrazine, Dicamba, 2, 4-D, Metolachlor, mecoprop, propanil, Urea derivatives, etc.

Fungicides

These pesticides are used against fungi and spores; they either eliminate or retard the growth of fungi and spores. These compounds damage the cell membrane; inactivate proteins, retards respiration and other metabolic activities in the fungi and spores (Sharma et al, 2022). In the early days, inorganic fungicides such as sulfur, copper, cadmium, tin, and mercury compounds were used as fungicides. Later on, the inorganic fungicides were replaced with efficient organic pesticides such as Difenoconazole, Mancozeb, Dithiocarmate, Diazines, Triazoles, Diazoles, etc. Those fungicides that inhibit only a specific site of fungal metabolic activities are called single-site fungicides, while those that disrupt several metabolic activities in the host body are called multi-site fungicides. (Garud et al., 2024).

Nematicides

Nematicides are those chemical compounds that are used to control the growth of non-segmented, microscopic crop-damaging worms called nematodes. The nematodes attack the root system of crops by reducing water and nutrient absorption capacity of the roots (Makhubu et al., 2021). The nematicides either kill the nematodes or reduce egg hatching or interfere with the root-finding ability of nematodes (Subedi et al., 2020). The nematicides used are of two types: i) Those nematicides that move through soil in the form of gas are known as fumigant Nematicides, such as Telone, chloropicrin, and methyl bromide; ii) while those which are in liquid or granular form (lower volatility), water soluble are called non-fumigant nematicides (Oxamyl, carbofuran, aldicarb, terbufos, fenamiphos, etc.).

Acaricides

These are those pesticides that kill ticks and mites that are vectors of several pathogens, bacteria, protozoa, and viruses causing/spreading diseases such as Lyme disease, anaplasmosis, and tick-borne encephalitis (Madison-Antenucci et al., 2020). These compounds in the agriculture sector are used to control those mites and ticks that feed on plants. Dichlorodiphenyltrichloroethane (DDT), organophosphates, carbamates, pyrethroids, and avermectins are commonly used as acaricides.

Rodenticides

These are those pesticides that are used to eliminate rodents (mice, rats, squirrels, woodchucks, bats) that damage the crop (Govindarajan et al., 2021). Rodenticides interfere with the functioning of the nervous system and disrupt normal blood clotting in the rodent, resulting in the death of the rodent. Widely used rodenticides are alpha-naphthyl thiourea, warfarin, bromadiolone, zinc phosphide, etc.

Based on toxicity

The World Health Organization (WHO) has classified pesticides on the basis of their LD_{50} (dose required to kill 50% of the test population) for rats as:

Class	Toxicity Level	LD_{50} for the rats (mg/kg body weight	
		Oral	Dermal
I	Extremely hazardous	< 5	< 50
II	Highly Hazardous	5-50	>50
III	Moderately Hazardous	50-200	200-500
IV	Slightly Hazardous	200-2000	500-2000

Based on mode of formulation

Based on formulation, the pesticides are classified as:

Solids

Solid formulation may be in the form of i) dust- applied directly without water after dilution with inert diluents, ii) Granules- active ingredient is mixed with clay, iii) Wettable Powders- In water suspension forming powder, require constant agitation before application, and iv) Baits**:** Active ingredient is mixed with food used for insects, rodents, or birds.

Liquids

Liquid Formulations are i) Emulsifiable Concentrates (EC): Active ingredients that are oil-soluble forms emulsion with water and are used in the form of an emulsion, ii) Solutions (SL): Ingredients that are water-soluble are used as a solution.

Gases/aerosols

Gas/Aerosol Formulations are I) Fumigants: The active ingredient in the environment becomes in gaseous form, generally applied in soil, ii) Aerosol Dispensers: Liquids are sprayed in the form of aerosol by a pressurized dispenser.

The main sources of pesticides in the environment

Agricultural Practices

The pesticides are mainly used in agricultural fields to increase crop growth by protecting plants from pests. The various modes of pesticide entering the environment are i) spray drifting and losses during application; ii) runoff from treated fields; iii) leaching from soil to groundwater; iv) volatilization from plant leaves and soil, and v) evaporation from surface water.

Domestic and Industrial sources

Domestic wastewater also contains pesticides (pesticides are used in building materials, in pet shampoos, and in lice removal shampoos). Leaks and spills from storage sites, improper disposal of containers, and residual waste also contribute pesticides to the environment.

Landfill and waste sites

Pesticides contaminate soil and groundwater via leaching from landfills and improper waste management.

Atmospheric Transport

Wind erosion causes the entry of volatile pesticides into the air.

Route of Pesticide Exposure

Humans are directly exposed to pesticides in the workplace and through agricultural and household activities, and indirectly exposed via contaminated air, water, soil, and food chain (Asefa et al., 2024). Pesticides enter the human body mainly via Dermal (skin), inhalation (lungs), ingestion (mouth), and ocular (eyes) (Simas et al., 2021; Yan et al., 2021).

Ingestion

Ingestion refers to consuming pesticide-contaminated food, vegetables, fruits, meat, milk, seafood (including fish), and/or drinking water, or beverages. The gastrointestinal route serves as a primary pathway for the entry of these substances into the body.

Dermal

Dermal uptake involves absorption through skin/gills. Aquatic animals bioaccumulate pesticides through this route from contaminated water. In humans, dermal absorption can occur during washing or bathing with contaminated water, using shampoos or cosmetic products containing pesticides, and/or during pesticide application and handling.

Inhalation

Inhalation uptake occurs when animals/humans breathe in pesticide vapors, dusts, or mists, especially during application, mixing, or in poorly ventilated areas.

Ocular (Eyes)

Ocular exposure occurs when pesticides enter the eyes, either from rubbing the eyes with contaminated hands or through splashes during pesticide mixing or application.

Neurotoxicity to aquatic organisms

Pesticides in aquatic environments, even at very low concentrations, exert profound toxic effects on aquatic organisms, particularly by impairing the central nervous system (CNS) of fish and other species. Grisotto et al. (2025) reported that rotenone (ROT) and deltamethrin (DM) induce extensive cell death in sensory, motor, and cognitive regions of the fish brain. Deltamethrin, in particular, damages neural areas associated with learning, memory, and decision-making. Supporting this, Badruzzaman et al. (2021) showed that rotenone contamination in the Ganga River caused significant neurobehavioral changes in *Mystus cavasius* fish due to neuronal loss. Zhang et al. (2025) demonstrated that abamectin, an insecticide, miticide, and nematicide, induces severe neurotoxicity in zebrafish embryos by impairing brain development. Abamectin exposure suppresses antioxidant enzyme activity, enhances reactive oxidative stress, and triggers neuroapoptosis in the embryonic brain (Formicki et al., 2025). Witeska (2024), in studies on *Cyprinus carpio*, observed that the herbicide dithiopyridine decreases neurotransmitter catecholamine levels while elevating acetylcholine (ACh), thereby disrupting sensory, cognitive, and motor functions. The study further concluded that organophosphorus pesticides exhibit the strongest neurotoxic effects, followed by carbamates, organochlorines, and pyrethroids. Atama et al. (2020) reported that pesticide exposure in catfish results in permanent and irreversible neurodegeneration, neuronal loss, and neurological dysfunctions. Mishra et al. (2022) similarly found that chlorpyrifos and indoxacarb adversely affect the neuronal physiology of catfish. Fitzgerald et al. (2021) documented that insecticides impair neuronal signaling, sensory processing, and motor outputs in fish, while Chew et al. (2020) observed pesticide-induced neurodegeneration in fish analogous to that seen in mammals. Additionally, Kar and Senthilkumaran (2024) documented significant neuroendocrine disruption in pesticide-exposed catfish.

Neurotoxicity to terrestrial animals

The nervous system is one of the most complex systems in organisms and includes the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS, comprising the brain, spinal cord, and/or nerves, is responsible for various neurological functions such as sensation, motor control, learning, memory, emotion, and sleep. The central nervous system also regulates the visceral physiological functions (Thau et al., 2025). In any organism, the cerebral and spinal nerves that constitute the peripheral nervous system collect and transmit information to organs through neurons (Murtazina and Adameyko, 2023). As per the report of GBD 2021 Nervous System Disorders Collaborators (2021) publication in Lancet Neurology, since 1990, the major global cause of disability in animals is neurological disorders. Grezenko et al. (2023) and Peedicayil (2023), during their studies, reported that environmental factors play a key role in the neurological and psychiatric disorders in both animals and humans. A survey of literature denotes that one of the major causes of neurotoxicity in animals is improper use of and environmental exposure to pesticides. Bartholomew et al. (2024) reported that herbicides glyphosate (most widely used) and glufosinate–ammonium phosphate induce cognitive and motor dysfunction, symptoms of neurotoxicity, in animals, particularly in rats. Leng et al. (2025) and Kang et al. (2021) have shown that the pesticides tebuconazole and azoxystrobin negatively impact the neurodevelopment of non-target organisms and increase the risk of neurotoxicity, leading to neurodegenerative diseases and motor dysfunction (Altun et al., 2025; Dong et al., 2024). Several health science researchers (Mudyanselage et al. 2023; Lucero and Muñoz-Quezada, 2021) have found that organophosphate, methylcarbamate, and pyrethroid insecticides cause synaptic dysfunction in both animals and humans, resulting in neurodevelopmental disorders, sensory conduction abnormalities, and emotional disturbances. Exposure of animals to plant growth regulators, such as gibberellic acid and indole-3-butyric acid, even at very small concentrations, adversely impacts neurologically relevant enzymes, resulting in neurological dysfunction (Kućko et al., 2025). Several researchers have reported memory loss and impaired recognition in rats exposed to different pesticides (Hou et al., 2023; Kaikai et al., 2023; More-Gutierrez et al., 2021). The literature further indicates that bees, mice, rats, bats, and mosquitoes exposed to organophosphates, carbamates, pyrethroids, and neonicotinoids exhibit memory and learning deficits (Honatel et al., 2024).

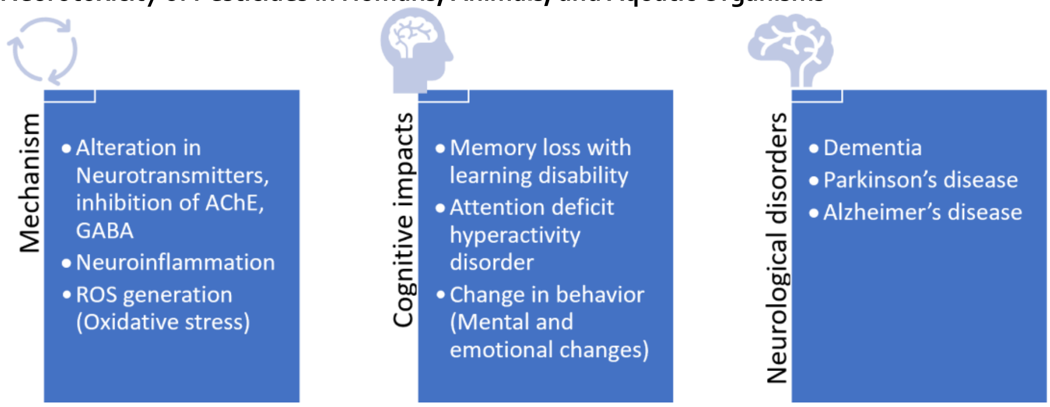
Neurotoxicity to humans

Environmental pollutants, particularly pesticides, enhance the environmental stress-induced neurotoxicity and contribute to the progression of neurodegenerative disorders, especially in the ageing population. These environmental stressors cause a variety of adverse effects, such as cell death, enhanced oxidative stress, β-oxidation of fatty acids, mitochondrial dysfunction, etc. Such alteration disrupts neurotransmission mechanisms, resulting in the aggravation of neurodegenerative diseases. Literature surveys indicate that prolonged exposure even to very low concentrations of pesticides has adverse effects on the central nervous system (comprising of brain, spinal cord, neurons, and nerves) (Costa-Ferreira et al., 2022), leading to neurodegenerative disorders such as Alzheimer's disease (AD), Parkinson's disease (PD), and multiple sclerosis (Moura et al, 2023).

Studies (Sparks et al. 2021; Rezende-Teixeira et al., 2022; Seralini et al., 2021) reveal that neurotoxic effects in humans by carbamate and organophosphate pesticides exert neurotoxic effects in humans primarily by inhibiting the enzyme acetylcholinesterase (AChE), thereby hindering the breakdown of acetylcholine, a key neurotransmitter. The organochlorine pesticides modulate GABA receptor activity, disrupting the neurotransmission. Disturbance in GABAergic signaling has also been associated with DNA damage in brain tissues, neurol hyperexictability and seizures (Seralini et al., 2021). It is also reported that pyrethroids and organophosphate pesticides induce oxidative stress (Alizadeh et al., 2022), leading to neuronal damage, altered cellular function, and increased susceptibility to neurodegenerative diseases. Amaral et al. (2025) reported that the pesticide rotenone inhibits mitochondrial complex I, causing a significant neuroinflammatory response.

Research studies (Zheng et al., 2023; Dara et al., 2023) have further demonstrated that neurotoxicity plays a major role in the etiology of both Parkinson's and Alzheimer's diseases. Alzheimer's disease (AD) is rapidly becoming a widespread neurotoxic disorder among the elderly population around the world (Liu et al. 2023). Patients with AD exhibit cognitive, behavioral, and functional impairments. Pesticides in the brain promote hyperphosphorylation of amyloid-β (Aβ) plaques and tau protein, leading to neurofibrillary tangles and neurotrophic neurites, thereby increasing the risk of AD. Pesticide exposure also enhances AChE activity, which reduces acetylcholine levels and contributes to AD progression. Parkinson's disease (PD), the fastest-growing neurodenerative disorder worldwide with no effective cure, is primarily characterized by the degeneration of dopaminergic (DA) neurons in the basal ganglia. Pesticides-induced disruptions of mitochondrial function and altered xenobiotic metabolism have been implicated as contributing factors in PD development (Rajawat et al. 2023; Martinez-Chacon et al., 2021). Research studies have shown that the risk of developing PD is influenced not only by environmental factors but also by age, and sex and genetic predisposition. Studies (See et al. 2022; Alizadeh et al., 2022; Colle, 2021) highlight mitochondrial dysfunction, oxidative injury, endoplasmic reticulum stress, inactivation of tyrosine hydroxylase, alteration in dopamine catabolism, and reduced brain-derived neurotrophic factor as major pathways involved in PD pathology.

Neurotoxicity of Pesticides in Humans, Animals, and Aquatic Organisms



Conclusion

Pesticides play a vital role in enhancing agricultural productivity and in controlling vector-borne diseases in public health; however, their indiscriminate use over the past five decades has raised significant concerns. Evidence indicates that even low-dose exposure to pesticides can produce neurological effects in aquatic organisms, animals, and humans. Research demonstrates that such exposure can alter both the structure and function of the nervous system across species. Mechanistically, pesticides induce oxidative stress, trigger inflammatory responses, and disrupt neurotransmission pathways, all of which contribute to neurodegeneration. In humans, pesticide exposure has been associated with Alzheimer's disease, Parkinson's disease, cognitive decline, memory impairment, and behavioral disturbances, with similar outcomes observed in animals and aquatic organisms. Furthermore, exposure during early developmental stages can adversely affect neurodevelopment, leading to long-term functional deficits.

References

Ahmad MF, Ahmad FA, Alsayegh AA, et al. (2024) Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures. Heliyon 10(7); e29128. DOI: 10.1016/j.heliyon.2024.e29128

Alizadeh S, Anani-Sarab G, Amiri H, et al. (2022) Paraquat induced oxidative stress, DNA damage, and cytotoxicity in lymphocytes. Heliyon 8(7): e09895. DOI: 10.1016/j.heliyon.2022.e09895.

Altun S, Özdemir S, Arslan H, et al. (2025) Impact of long-term deltamethrin exposure on Alzheimer's-related neurodegeneration in rats. Experimental Neurology 388: 115223. DOI: 10.1016/j.expneurol. 2025. 115223.

Amaral L, Martins M, Côrte-Real M, et al. (2025) The neurotoxicity of pesticides: Implications for Parkinson's disease. Chemosphere 377:144348. DOI: 10.1016/j.chemosphere.2025.144348.

Asefa M, Mergia M, Damtew YT, et al. (2024) Organochlorine pesticides in Ethiopian waters: Implications for environmental and human health. Toxicology Reports 12: 622-630. DOI: 10.1016/j.toxrep.2024.06.001

Atama CI, Nnaji EC, Ezeoyili IC, et al. (2020) Neuromodulatory and oxidative stress evaluations in African catfish Clarias gariepinus exposed to antipsychotic drug chlorpromazine. Drug and Chemical Toxicology 45 (3): 1318-1324.

Badruzzaman, M, Shajahan M, Roy PK, et al. (2021) Rotenone alters behavior and reproductive functions of freshwater catfish, Mystus cavasius, through deficits of dopaminergic neurons in the brain. Chemosphere 263:128355.

Bartholomew SK, Winslow W, Sharma R, et al. (2024) Glyphosate exposure exacerbates neuroinflammation and Alzheimer's disease-like pathology despite a 6-month recovery period in mice. Journal of Neuroinflammation 21: 316. DOI: 10.1186/s12974-024-03290-6

Bhatt C, Saha A, Khalkho BR and Rai MK (2024) Spectroscopic Determination of Permethrin Insecticide in Environmental and Agricultural Samples Using Leuco Crystal Violet Reagent. Environ Sci Arch 3(1): 14-28.

Casillas A, de la Torre A, Navarro I, et al. (2022) Environmental risk assessment of neonicotinoids in surface water. Science of The Total Environment 809:151161. DOI: 10.1016/j.scitotenv.2021.151161

Chen Z, Zhao L, Kang, S, et al. (2025) Toxicity and environmental fate of the less toxic chiral neonicotinoid pesticides: a review. Environmental Chemistry Letters 23: 733–750.DOI: 10.1007/s10311-024-01808-1.

Chen Y, Meng R, Liu G, et al. (2025) Neonicotinoide pesticide residues in bottled water: a worldwide assessment of distribution and human exposure risks. Environmental Science: Processes Impacts 27: 1960-1970

Chew SF, Tan SZ, Ip SC, et al. (2020) The non-ureogenic stinging catfish, Heteropneustes fossilis, actively excretes ammonia with the help of Na+/K+-ATPase when exposed to environmental ammonia. Frontiers in Physiology 10: 161

Clabo D and Dickens ED (2021) Old-field planted longleaf pine survival and growth response to various herbaceous weed control herbicides and application timings after 11 years. New Forests 53:871-892. DOI: 10.1007/s11056-021-09891-w

Colle D and Farina M (2021) Oxidative stress in paraquat-induced damage to nervous tissues, Toxicology, Elsevier2021, pp. 69-78.

Costas-Ferreira C, Durán R and Faro LRF (2022) Toxic Effects of Glyphosate on the Nervous System: A Systematic Review. International Journal Molecular Science 23(9):4605. DOI: 10.3390/ijms23094605.

Dara D and Drabovich AP (2023) Assessment of risks, implications, and opportunities of waterborne neurotoxic pesticides. Journal of Environmental Science 125:735–741. DOI: 10.1016/j.jes.2022.03.033.

Das K, Pramanik S, Rajak P, Biswas G and Mandi M (2024) Monocrotophos induced changes in the life cycle parameters of fruit fly. Environ Sci Arch 3(STI-1): 6-13.

Dong B. (2024) A comprehensive review on toxicological mechanisms and transformation products of tebuconazole: Insights on pesticide management. Science Total Environment 908:168264.DOI: 10.1016/j. scitotenv.2023.168264.

Ferrari L and Speltini A (2023) Neonicotinoids: An overview of the newest sample preparation procedures of environmental, biological and food matrices. Advances in Sample Preparation 8:100094. DOI: 10.1016/j.sampre.2023.100094.

Fitzgerald JA, Könemann S, Krümpelmann L, et al. (2021) Approaches to test the neurotoxicity of environmental contaminants in the zebrafish model-from behavior to molecular mechanisms, Environmental Toxicology and Chemistry 40(4), 989-1006, DOI: 10.1002/etc.4951

Flores-Gutierrez CA, Torres-Sanchez ED, Reyes-Uribe E, et al. (2023) The Association between Pesticide Exposure and the Development of Fronto-Temporal Dementia-Cum-Dissociative Disorders: A Review. Brain Science 13(8):1194. DOI: 10.3390/brainsci13081194.

Formicki G, Goc Z, Bojarski B, et al. (2025) Oxidative Stress and Neurotoxicity Biomarkers in Fish Toxicology. Antioxidants (Basel).14(8):939. DOI: 10.3390/antiox14080939.

Foucault A, Vallet N, Ravalet N, et al. (2021) Occupational pesticide exposure increases risk of acute myeloid leukemia: a meta- analysis of case–control studies including 3,955 cases and 9,948 controls. Science Reporter 11 (1): 1–13.

Friedman A, Janulewicz Lloyd PA, Carlson J, et al. (2022) Preliminary Findings from the Gulf War Women's Cohort: reproductive and Children's Health Outcomes among Women Veterans. International Journal Environmental Research Public Health 19(14):8483. DOI: 10.3390/ijerph19148483

Frisoni GB, Altomare D, Thal, et al. (2022) The probabilistic model of Alzheimer disease: the amyloid hypothesis revised, Nat. Rev. Neuroscience 23 (1): 53–66. DOI: 10.1038/s41583-021-00533-w

Fucic A, Duca RC, Galea KS, et al. (2021) Reproductive health risks associated with occupational and environmental exposure to pesticides. International Journal Environmental Research Public Health 18(12): 6576

Garud A, Pawar S, Patil MS, et al. (2024) A Scientific Review of Pesticides: Classification, Toxicity, Health Effects, Sustainability, and Environmental Impact. Cureus 16(8):e67945. DOI: 10.7759/ cureus. 67945.

Grisotto J, Tavakolian HS, Sasan AP, et al. (2025) Neurotoxic effects of rotenone and deltamethrin prolonged exposure on adult zebrafish. Science Reporter 15: 27126. DOI:10.1038/s41598-025-13273-z

Gerken J, Vincent GT, Zapata D, et al. (2024) Comprehensive assessment of pesticide use patterns and increased cancer risk. Frontier Cancer Control Society 2:1368086. DOI: 0.3389/fcacs.2024.1368086

Govindarajan R, Ramamoorthy G, Shanmugam RM, et al. (2021) Rodenticide ingestion is an important cause of acute hepatotoxicity in Tamil Nadu, southern India. Indian Journal Gastroenterology 40(4):373-379. DOI: 10.1007/s12664-021-01178-4

Grezenko H, Ekhator C, Nwabugwu NU, et al. (2023) Epigenetics in Neurological and Psychiatric Disorders: A Comprehensive Review of Current Understanding and Future Perspectives. Cureus 15(8):e43960. DOI: 10.7759/cureus.43960

Hashimi MH and Ryan Q. (2020) Toxic Effects of Pesticides on Humans, Plants, Animals, Pollinators and Beneficial Organisms. Asian Plant Research Journal 5(4): 37-47. DOI: 10.9734/APRJ/2020/v5i430114

Hern´andez-Mariano J´A, Baltazar-Reyes MC, Salazar-Martínez et al. (2022) Exposure to the pesticide DDT and risk of diabetes and hypertension: systematic review and meta-analysis of prospective studies, International Journal Hygiene Environment Health 239:113865.

Hirano T, Suzuki N, Ikenaka Y, et al. (2021) Neurotoxicity of a pyrethroid pesticide deltamethrin is associated with the imbalance in proteolytic systems caused by mitophagy activation and proteasome inhibition. Toxicology and Applied Pharmacology, 430:115723. DOI: 10.1016/j.taap.2021.115723.

Honatel KF, Arbo BD, Leal MB et al. (2024) An update of the impact of pesticide exposure on memory and learning. Discover Toxicology, 1:11 DOI: 10.1007/s44339-024-00011-9.

Hou L, Liu J, Sun F, et al. (2023) Integrin Mac1 mediates paraquat and maneb-induced learning and memory impairments in mice through NADPH oxidase-NLRP3 infammasome axis dependent microglial activation. Journal of Neuroinflammation 20:42.

Kaikai N, Ba- M'hamed S, Ghanima A, et al. (2023) Exposure to metam sodium based pesticide impaired cognitive performances in adult mice: involvement of oxidative damage and glial activation. Toxicological Applied Pharmacology 477:11667.

Kang J, Bishayee K and Huh S-O. (2021) Azoxystrobin Impairs Neuronal Migration and Induces ROS Dependent Apoptosis in Cortical Neurons. International Journal Molecular Science 22(22):12495. DOI: 10.3390/ijms222212495

Khan BA, Nadeem MA, Nawaz H, et al. (2023) Pesticides: impacts on agriculture productivity, environment, and management strategies, Emerging Contaminants and Plants: Interactions, Adaptations and Remediation Technologies, Springer2023, pp. 109-114

Kar S and Senthilkumaran B. (2024) Recent advances in understanding neurotoxicity, behavior and neurodegeneration in siluriformes. Aquaculture and Fisheries, 9(3): 404-410. DOI: 10.1016/j.aaf.2023. 08. 009

Kaushal S and Singh Z (2022) Organic Farming: A Step towards Better Environment. Environ Sci Arch 1(2):53-59.

Kim B, Park EY, Kim J, et al. (2022) Occupational exposure to pesticides and lung cancer risk: a propensity score analyses. Cancer Research Treatment 54:130–139. DOI: 10.4143/crt.2020.1106.

Kućko A, Walczak A, Wilmowicz E, et al. (2025) Allies or Enemies? The Power of Plant Hormones in Animals: Insights into Their Regulatory Roles. Molecules, 30(14):2984. DOI: 10.3390/molecules30142984

Leng Y, Zeng Y, Zhang Y, et al. (2025) Neurotoxic risks of long-term environmental exposure to pesticides: a review. Chemico-Biological Interaction, 418: 111626. DOI: 10.1016/j.cbi.2025.111626.

Liu H, Reynolds GP and Wei X.(2023) The influence of agricultural work and plasma uric acid on hospital admission for alzheimer's disease. Journal Alzheimer Disease 2023:1–5. DOI: 10.3233/JAD-221226.

Lucero B and Muñoz-Quezada MT. (2021) Neurobehavioral, Neuromotor, and Neurocognitive Effects in Agricultural Workers and Their Children Exposed to Pyrethroid Pesticides: A Review. Frontier Human Neuroscience 15:648171. DOI: 10.3389/fnhum.2021.64817

Madison-Antenucci S, Kramer LD, Gebhardt LL, et al. (2020) Emerging Tick-Borne Diseases. Clinical Microbiology Review 33(2):e00083-18. DOI: 10.1128/CMR.00083-18.

Makhubu FN, Khosa MC and McGaw LJ. (2021) South African plants with nematicidal activity against root-knot nematodes: A review. South African Journal of Botany 139: 183-191. DOI: 10.1016/j. sajb.2021. 02.010.

Martínez-Chacón G, Yakhine-Diop SM, González-Polo RA, et al. (2021) Links between Paraquat and Parkinson's Disease, Handbook of Neurotoxicity; pp. 1–19.

Matich EK, Laryea JA, Seely KA, et al. (2021) Association between pesticide exposure and colorectal cancer risk and incidence: A systematic review. Ecotoxicology Environmental Safety 219:112327. DOI: 10.1016/j.ecoenv.2021.112327

Mehra S and Chadha P (2023) Molecular Biomarkers as Key Factors to Evaluate the Extent of Industrial Pollution Exposure. Environ Sci Arch 2(STI-2):18-22.

Mishra AK, Gopesh A and Singh KP. (2022) Acute toxic effects of chlorpyrifos on pseudobranchial neurosecretory system, brain regions and locomotory behavior of an air-breathing catfish, Heteropneustes fossilis (Bloch 1794). Drug and Chemical Toxicology, 45 (2): 670-679

Mohd Ghazi R, Nik Yusoff NR, Abdul Halim NS, et al. (2023) Health effects of herbicides and its current removal strategies. Bioengineering 14(1):2259526. DOI: 10.1080/21655979.2023.2259526

Montull JM and Torra J. (2023). Herbicide resistance is increasing in Spain: concomitant management and prevention. Plants (Basel, Switzerland), 12(3):469. DOI: 10.3390/plants12030469

Mora-Gutiérrez A, Guevara J, Rubio C, et al. (2021) Clothianidin and Thiacloprid Mixture Administration Induces Degenerative Damage in the Dentate Gyrus and Alteration in Short-Term Memory in Rats. Journal Toxicology 2021: 9983201.

Moreira S, Silva R, Carraget DF, et al. (2022) Carbamate Pesticides: Shedding Light on Their Impact on the Male Reproductive System. International Journal Molecular Science 23(15): 8206; DOI: 10.3390/ ijms 23158206

Moura DD,Borges V, Ferraz HB, et al. (2023) History of high household pesticide use and Parkinson's disease in Brazil. Parkinsonism & Related Disorders 113:105493. DOI:10.1016/ j.parkreldis.2023.105 493.

Mudyanselage AW, Wijamunige BC, Kocon A, et al. (2023) Differentiated Neurons Are More Vulnerable to Organophosphate and Carbamate Neurotoxicity than Undifferentiated Neurons Due to the Induction of Redox Stress and Accumulate Oxidatively-Damaged Proteins. Brain Science 13(5):728. DOI: 10.3390/brainsci13050728

Murtazina A and Adameyko (2023) The peripheral nervous system. Development 150 (9): dev201164. DOI: 10.1242/dev.201164.

Nervous System Disorders Collaborators (2021) Global, regional, and national burden of disorders affecting the nervous system, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021.Lancet Neurology 2024; 23: 344–381. DOI: 10.1016/ S1474-4422(24)00038-3

Nguyen A, Crespi CM, Vergara X, et al. (2023) Pesticides as a potential independent childhood leukemia risk factor and as a potential confounder for electromagnetic fields exposure. Environmental Research, 238(1): 116899. DOI: 10.1016/j.envres.2023.116899.

Nuryati A, Rahardjo SS and Murti B. (2022) Pesticide Exposure and Its Correlation with Hemoglobin and Cholinesterase in Farmers Who Used Pesticide. Journal of Epidemiology and Public health 7(3): 10. DOI: 10.26911/jepublichealth.2022.07.03.10

Ocmen E, Erdost HA and Hanci V, (2023) The bibliometric analysis of most cited 100 papers in anesthesia-induced neurotoxicity. Medicine 102(48): e36508. DOI: 10.1097/MD.0000000000036508.

Pandey P, Chakole S, Wanjari MB, et al. (2023) A bibliometric analysis of scientific research publications related to pesticide poisoning in the South Asian countries. Cureus 15(4): e38134.DOI:10.7759/ cureus. 38134.

Pathak VM, Verma VK, Rawat BS, et al. (2022) Current status of pesticide effects on environment, human health and it's eco-friendly management as bioremediation: A comprehensive review. Frontier Microbiology13:962619. DOI: 10.3389/fmicb.2022.962619.

Peedicayil J. (2023) Genome–Environment Interactions and Psychiatric Disorders. Biomedicines 11(4): 1209. DOI: 10.3390/biomedicines11041209

Perrin L, Spinosi J, Chaperon L, et al. (2021) Pesticides expenditures by farming type and incidence of Parkinson disease in farmers: a French nationwide study. Environmental Research 197:111161. DOI: 10.1016/j.envres.2021.111161

Rafeeinia A, Asadikaram G, Moazed V, et al. (2022). Organochlorine pesticides may induce leukemia by methylation of CDKN2B and MGMT promoters and histone modifications. Gene, 851: 146976. DOI: 10.1016/j.gene.2022.146976.

Rajawat NK, Bhardwaj K and Mathur N. (2023) Risk of Parkinson disease associated with pesticide exposure and protection by probiotics. Mater Today: Proc. 69:A1–A11.

Rani L, Thapa K, Kanojia N, et al. (2021) An extensive review on the consequences of chemical pesticides on human health and environment, Journal Cleaner Production. 283: 124657. DOI: 10.1016/j.jclepro. 2020. 124657.

Rezende-Teixeira P, Dusi RG, Jimenez PC, et al. (2022) What can we learn from commercial insecticides? Efficacy, toxicity, environmental impacts, and future developments. Environmental Pollution 300:118983. DOI: 10.1016/j.envpol.2022.118983

See WZC, Naidu R and Tang KS. (2022) Cellular and molecular events leading to paraquat-induced apoptosis: mechanistic insights into Parkinson's disease pathophysiology. Molecular Neurobiology 59(6):3353–3369. DOI: 10.1007/s12035-022-02799-2

Seralini G and Jungers G. (2021) Endocrine disruptors also function as nervous disruptors and can be renamed endocrine and nervous disruptors (ENDs) Toxicological Reports 8:1538–1557. DOI: 10.1016/ j.toxrep.2021.07.014.

Sharma K, Aaghaz S, Maurya IK, et al. (2022) Antifungal evaluation and mechanistic investigations of membrane active short synthetic peptides-based amphiphiles. Bioorganic Chemistry 127:106002. DOI: 10.1016/j.bioorg.2022.106002

Shekhar C, Khosya R, Thakur K, et al. (2024) A systematic review of pesticide exposure, associated risks, and long-term human health impacts. Toxicology Reports 13:101840. DOI: 10.1016/j.toxrep.2024.101840

Sidthilaw S, Sapbamrer R, Pothirat C, et al. (2022) Effects of exposure to glyphosate on oxidative stress, inflammation, and lung function in maize farmers, Northern Thailand. BMC Public Health 22(1): 1343. DOI: 10.1186/s12889-022-13696-7

Simas JMM, Yamauchi LY and De Alencar MDB (2021) Risk Factors Associated Among Respiratory Health and Banana Farming. Archieves Environmental Occupational. Health 76: 181–187.

Singh G (2025) From Backpacks to Blades: A New Era of Pesticide Spraying. Environmental Science Archives 4(2): 543-546.

Sidhu MS and Singh S (2025) Nanopesticides and 'All-Organic' Nanopesticide Synthesis, Classification and their Use in Agriculture. Environmental Science Archives 4(1): 274-288.

Somé EN, Traoré IT, Tamdamba S, et al. (2022) Association between pesticide exposure and infertility of couple in the Boucle du Mouhoun region: A case-control study. Clinical Epidemiology and Global Health 17:101156. DOI: 10.1016/j.cegh.2022.101156

Song L, He X, Wang M, et al. (2023). IFN-γ mediated neuroinflammation and behaviour abnormality after maternal exposure to low dose mixture of food additives and pesticides. Food and Agricultural Immunology 34(1):2226841. DOI: 10.1080/09540105.2023.2226841.

Food and Agricultural Immunology 34(1):2226841. DOI: /10.1080/09540105.2023.2226841.

Sparks TC, Storer N, Porter A, et al. (2021) Insecticide resistance management and industry: the origins and evolution of the Insecticide Resistance Action Committee (IRAC) and the mode of action classification scheme. Pest Management Science 77(6):2609–2619. DOI:10.1002/ps.6254.

Subedi S, Thapa B and Shrestha J. (2020) Overview of root-knot nematode (Meloidogyne incognita) and control management. Journal of Agriculture and Natural Resources 3(2): 21-31. DOI: 10.3126/janr. v3i2. 32298

Thau L, Reddy V and Singh P. (2025) Anatomy, Central Nervous System.Treasure Island (FL): StatPearls Publishing; Jan 2025.

Tudi M, Ruan HD, Wang L, et al. (2021) Agriculture Development, Pesticide Application and Its Impact on the Environment. International Journal Environmental Research Public Health 18(3):1112. DOI: 10. 3390/ ijerph18031112

USEPA. (2023) Pesticides to Control Bed Bugs

Wan NF, Fu L, Dainese M, et al. (2025) Pesticides have negative effects on non-target organisms. Natural Communication 16: 1360. DOI: 10.1038/s41467-025-56732-x

Witeska M. (2024) Neurotoxicity Biochemical Biomarkers in Fish Toxicology. Preprints 09: 1610. DOI: 10.20944/ preprints202409.1610.v1

Yan XJ, Zhou YY, Liu XH, et al. (2021) Minimizing Occupational Exposure to Pesticide and Increasing Control Efficacy of Pests by Unmanned Aerial Vehicle Application on Cowpea. Applied Science 11: 9579.

Zhang H, Liu Y, Huang Y, et al. (2025) Abamectin Causes Neurotoxicity in Zebrafish Embryos. Inte J Mol Sci. 26(1):349. DOI: 10.3390/ijms26010349.

Zheng R, García-González J, Romero-del Rey R, et al. (2023) Occupational exposure to pesticides as a risk factor for sleep disorders. International Journal Environmental Research Public Health 20(4):3149. DOI: 10.3390/ijerph20043149.

Author Contributions
OPB conceived the concept, wrote and approved the manuscript.

Acknowledgements
The Author is thankful to all those researchers whose work has been referred to in this review article. No original data has been used in this review; all information accessed is from published work.

Funding
Not applicable.

Availability of data and materials
Not applicable.

Competing interest
The author declares no competing interests.

Ethics approval
Not applicable.

Citation: Bansal OP (2025) Pesticides and Neurotoxicity in Aquatic, Terrestrial Animals and Humans: A Review. Environmental Science Archives 4(2): 938-950.