

Effect of Pesticide Toxicity in Aquatic Ecosystem: An overview

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ABSTRACT

Aquatic ecosystem and all biodiversity through out world has become major threat due to aquatic pesticide pollution. These pesticides are catagories as carbamates, organophosphate neonicotinoid, insecticides these are enter in marine as well as freshwater through runoff from agricultural, urban discharge and industrial effulents. These affect the physiology, behaviour, reproductive capacity of different non target animals including such as vertebrates fishes amphibian zooplankton invertebrates etc this disturbed the aquatic food webs. long term exposure of different chemical pesticides can change the community structure and weak the ecological resilience through bio-accumulation and bio-magnification. different pesticides also affect ecological functions, nutrients cycle primary productivity. So strictly work on sustainable methods of agriculture integrated monitoring are needed to address these issues.

Keywords- Pesticides, agriculture effulents aquatic ecosystem, Biomagnification industrial effulents.

I. INTRODUCTION

Pesticides are used to control different pests, pathogens, and weeds. Those are chemical or synthetic in origin. It may be of different types, such as bactericides, insecticides, fungicides, rodenticides, and larvicides. They are important for food security and protect up to 45 percent of global food production from destruction. Modern agriculture relies on these agents to improve yield quality and quantity while reducing production losses (Abhilash et al., 2009).

Rapid economic development after the post-World War period triggered a significant rise in the production and application of pesticides, important for boosting food security over the last 50 years. This rise has created substantial environmental and health challenges. Pesticides are commonly categorized according to their chemical composition into four primary groups: organophosphate, carbamate, and pyrethroids (Buchel, 1983). The oldest group of synthetic pesticides is organochlorine. Most of them are used as insecticides in agriculture and control of domestic insects. They persist for a long time in the

environment. Organochlorines disrupt the nervous system through their mechanism of action, leading to convulsion and paralysis in insects, which ultimately causes death. Some common examples of organochlorines are DDT (Dichloro Diphenyl Trichloroethane), Dieldrin, Aldrin, Lindane, Endosulfan, and Chlordane, etc., which have a long-term existence in the environment. Organochlorine insecticides act by disrupting the nervous system of insects, particularly by preventing the closure of sodium channels in nerve fibers, which causes repeated nerve discharge, creates hyper-excitability, paralysis, convulsion, and finally leads to death (Garg P.K. et al., 2021). From a long time, the use of DDT has been banned in developing countries (Jaacks et al., 2021). On a large scale, organophosphates are used as pesticides, which lead to contact poison, stomach poison, and nervous poison. Most of them are used as insecticides, such as glyphosate, diazinon, malathion, and parathion (Yadav et al., 2017; Karunarathne et al., 2021). Carbamates and organophosphates are similar in their structure and mode of action, but their origin is different (Drum C. et al., 1980).

Those pesticides, with 3.5 million consumption at the global level, almost belong to insecticides (Sharma A. et al., 2019). Massive pesticide use threatens roughly 64% of agricultural land globally, and 31% is considered very dangerous. Developing countries such as India, China, South Africa, Australia, and Argentina are the maximum related regions because of the threat of pollution risk (Kunstader, 2007). Due to pesticides, serious environmental problems are caused (Tang F. et al., 2021). The use of chemical pesticides is rapidly increasing in developing countries like Africa, Asia (Kunstader, 2007), the Middle East, and Eastern Europe (Zhang et al., 2011). The use of pesticides in rural areas is unsafe for the environment. It is noted that during the application of pesticides in fields, farmers do not follow proper safety rules. It has been proved by various studies that farmers have poor knowledge about the use of pesticides and safety protocols; these are infrequently used in agricultural fields (Berni et al., 2021; Pan et al., 2021). According to studies, the presence of pesticide residues in air, soil, and water leads to accumulation in the food chain, including mammals and various non-target species, which develop ecological imbalance. The aquatic environment supports life for all living things and its complex network of interrelated water, biota, and sediment (Iqbal et al., 2025). In aquatic ecosystems, hazardous organic and inorganic contaminants accumulate, which deteriorate water quality, cause ecological imbalance, and negatively affect human health (Barwant et al., 2025).

Pollution of aquatic ecosystems due to pesticides; pollution of rivers due to pesticides is a major source of concern in India. Maximum agricultural land is located near Indian river banks. So, there is a maximum chance of polluting rivers due to agricultural runoff (Agarwal et al., 2015). Previous studies indicate hexachlorocyclohexane, endosulfan, and DDT as crucial pollutants in water bodies and biota, while DDT, aldrin, dieldrin, and HCH are found in the sediment phase (Samanta, 2013). Many rivers of India, like the Ganga, Yamuna, and their tributaries, have been highly polluted due to pesticides (Asim S., 2021; Shah, 2021). Different pesticides have been detected in water samples of the Yamuna River (Agarwal et al., 2006). Research data analysis of the Gomti, another tributary of the Ganga River, showed the presence of heptachlor epoxides and DDT in river-bed sediments, which indicates accumulation in river-bed sediments (Malik et al., 2009). This way, pesticide pollution has caused widespread pollution of various major Indian rivers, such as the Ghaggar River in Haryana, the Hindon River in Uttar Pradesh, and the Cauvery River in Karnataka. This contamination is primarily due to agricultural runoff and municipal waste discharge (Kaushik et al., 2010; Nicolopoulou et al., 2016). Surface water samples and fish samples of the Tapi River showed the presence of chlorpyrifos, methyl parathion, and endosulfan. In fish samples, the detected levels of endosulfan, methyl

parathion, and chlorpyrifos were 101.28, 0.392, and 3.49 ng/g, respectively. These results revealed that highly toxic pesticides are still being used in surrounding areas. There is an urgent need to implement rules and control the production and application of such pesticides (Hashmi et al., 2020). Such studies also showed that in the Hooghly River Basin in West Bengal, India, insecticides predominated over herbicides, and the toxicity of a given combination of compounds may increase (Denneer, 2000). In all water samples, the presence of HCH and DDT was found above the upper limits prescribed for drinking purposes (Kaushik et al., 2010). The Indian Government has notified and suggested maximum residue limits under the Protection of Food Safety and Standards, Toxins, Contaminants, and Residual Regulations, 2011.

II. EFFECT OF PESTICIDE TOXICITY IN MICRO ORGANISM

Aquatic micro-fauna is affected by the toxicity of pesticides. These pesticides also run through agricultural runoff and spills. Pesticide toxicity also affects the function and structure of microbial fauna. These pesticides are bioaccumulated in ecosystems and also assimilated by microorganisms. The process of toxicity of pesticides in microbial fauna depends upon the type of microbes and chemicals assimilated by microorganisms. The toxicity of pesticides to soil bacteria depends on the species exposed to them (Garg et al., 2021).

Pesticides freely present in soil can adversely affect organisms such as *Pseudomonas*, *Penicillium*, and *Bacillus*, which can disrupt the aquatic ecosystem. The use of pesticides has been shown to reduce the abundance of microorganisms such as *Pseudothrobacter*, *Streptomyces*, and *Talaromyces* by 1.4 to 56.0 times, depending upon the type of pesticide (Prudnikova, 2021).

Excess use of pesticides negatively affects the abundance of nitrifying bacteria like *Nitrospira inopinata* in paddy soil fields (Rahman et al., 2021). The commercial application of organophosphate pesticides such as phosline, chlorophos, and dimethoate, along with pyrethroid insecticides such as alpha-cyhalothrin, significantly reduces soil microbial respiration, among which chlorpyrifos demonstrates the highest toxicity and resistance (Karpun et al., 2021).

III. EFFECT OF PESTICIDE ON AQUATIC INVERTEBRATES

Bioassays conducted on *Daphnia magna* and *Parachormis devil* using field-collected contaminated water confirm that *D. magna* is highly sensitive to pesticide exposure (Diepens et al., 2014). Additionally, neonicotinoid insecticides, like imidacloprid, pose a

significant threat to valuable shrimp aquaculture. Research on black tiger shrimp (*Penaeus monodon*) reveals that imidacloprid acts as a chemical stressor, triggering dose-dependent and time-dependent elevations in stress enzyme biomarkers present in the abdomen, gill, head, and hepatopancreas, etc. These highly affected enzymatic activities were correlated with the accumulation of imidacloprid in shrimp tissues. During regular monitoring, each response of biomarkers depicted that imidacloprid acts as an environmental chemical stressor for adult tiger shrimp (*Penaeus monodon*) (Garg et al., 2021; Jaacks et al., 2019).

Effect of different pesticides, neonicotinoid, flumethrin, acetamiprid, and pyrethroid were studied on primary gill, gonad, mantle, and digestive gland tissues of *Unio* sp. The result showed similarities to acetamiprid, and flumethrin was the most potent in inducing oxidative stress and tissue damage (Arslan et al., 2021). The high-risk percentage of most organophosphate pesticides was reported to be higher in *Daphnia* than in fish and algae (Sumon et al., 2018).

IV. IMPACT OF PESTICIDES ON AQUATIC VERTEBRATES

In India, several studies have been conducted to assess the impact of pesticides on aquatic vertebrates. In agriculture, the most commonly used pesticide is chlorpyrifos (Yen J., 2011). Bifenthrin is next used in agriculture, while it is also used in public health control programs, including mosquito control (Ponepal et al., 2010). Several research studies have been conducted to understand the genotoxic effects of mixtures of different pesticides. A study on the effect of bifenthrin and chlorpyrifos on Indian major carp, *Labeo rohita*, reported that 33% LC₅₀ increased with time. Time-dependent damage of DNA was observed up to 56 days of exposure to a sub-lethal dose, and after that, a slight decrease was observed in the next fourteen days (Bano et al., 2021).

Acetamiprid is globally used in agriculture for the management of pests in different crops (Zhang et al., 2011). Dimethoate is a broad-spectrum organophosphate pesticide that is widely used against mites and insects (Tarbah et al., 2007). When studying the comparative effects of dimethoate, chlorfenpyr, and acetamiprid in *Cirrhinus mrigala*, results showed major significant differences in blood parameters as well as thyroid profile. Furthermore, elevated liver marker enzymes were observed in the serum of pesticide-treated fish alongside significant histological damage to the gills and liver in all treated groups. The toxicity range of the three pesticides was chlorfenpyr, acetamiprid, and dimethoate.

Reports of studies showed extensively that these pesticides have serious effects on non-target organisms, human beings, and the whole ecosystem (Ghayyur et al., 2011). In agriculture, malathion is another organophosphate pesticide that is widely used for controlling a wide range of pests. It is not only

resistant to biodegradation but is also highly toxic. It remains for two generations after entering inside the human body (Kalantary et al., 2016). The application of a low dose of malathion on *Channa punctatus* fish (Bloch) was studied after different time intervals, which exhibited a high level of exposure to malathion. It caused a marked decrease in morphometric indices and different biochemical enzyme parameters, especially the antioxidant system (Bharti et al., 2021).

When *Catla catla* was chronically exposed to a sub-lethal concentration of cypermethrin, the activity of stress enzymes in its kidneys significantly increased initially after 15 days, followed by a decline over 50 days. Meanwhile, lipid peroxidation remained elevated throughout the exposure period. Analysis of histopathological studies revealed proliferation of haemopoietic tissue, as well as degeneration of kidney tubules and glomerulus. Additionally, ultrastructural studies showed cellular damage, cytoplasmic vacuolation, fragmented rough endoplasmic reticulum, proliferation of rough endoplasmic reticulum, proliferation of lysosomes, mitochondrial degeneration, and damage to the epithelial lining of renal tubules (Sharma et al., 2021).

In a study on the effect of cypermethrin on the reproductive behaviour of (*Salmo trutta* L.) brown trout in a large stream-water aquarium, young trout exposed to high ratios of cypermethrin showed disturbed reproductive behaviour. Observations such as fewer occurring events, spending less time near nesting females, low volume of strippable milt, and significantly low levels of 11-ketotestosterone were analysed (Jaenssen et al., 2007).

Additionally, the single and combined toxicological effects of some pesticides, namely chlorpyrifos, thiamethoxam, beta-cypermethrin, tetraconazole, and azoxystrobin, were studied on (*Gobiocypris rarus*) rare minnow. Results revealed that among all pesticides, beta-cypermethrin, chlorpyrifos, and azoxystrobin showed the highest toxicity to *G. rarus*. Larval forms of rare minnows were reported to be more sensitive to these pesticides compared with embryos. These pesticide mixtures exhibited synergistic toxicity to fish (Yang et al., 2020).

Amphibians are highly susceptible to pesticide pollution due to their specific habitat requirements and highly permeable skin (Mann, 2003). Studies on bioaccumulation of DDT were assessed in Muller's clawed frog (*Xenopus muelleri*) in the Lower Phongolo River floodplain of South Africa. The study showed that DDT concentrations in these frogs increased significantly over the study period (Wolmarans et al., 2018).

Different pollutants also affect the breeding period of adult water birds and cause developmental abnormalities in developing embryos. These embryonic defects cause mortality, reduced hatchability, failure of chick survival, and different teratological abnormalities,

such as abnormalities in the skeletal system, reproductive system, and nervous system through the mechanism of hormonal mimicking of estrogen. The chemical effects of different pesticides on water birds cause lethality, stress, mortality, reduced fertility rates, decreased egg formation, thinning of eggshells, impaired incubation, and altered chick-rearing behaviour (Fry D.M., 1995).

V. INDIAN LAWS FOR PROTECTION FROM PESTICIDES POLLUTION

India laws for protection of environmental resources: The Government of India has passed several measures and rules. In 1972, it passed the first law for the protection of wildlife and the environment through the National Committee on Environmental Planning and Coordination (Wildlife Protection Act, 1972).

Since then, three additional acts have been enacted at the Central Government level regarding water pollution and general environmental protection: the Water (Prevention and Control of Pollution) Act, 1974; the Water (Prevention and Control of Pollution) Cess Act, 1977; and the Environment (Protection) Act, 1986.

The Water Pollution Act of 1974 resulted in the establishment of Pollution Control Boards at both the Central and State levels. Sections 20, 21, and 23 of this law give local authorities jurisdiction to act in cases of water pollution. The Water Cess Act of 1977 allows the Pollution Control Board to charge water users a cess, enabling the Board to financially support its activities. This Act was amended in 2003 (CPCB Act, 1974, 1977, 1986).

These regulations govern the import, manufacture, transport, distribution, and use of insecticide pesticides to protect human beings and animals across India. All pesticides sold in India must mandatorily undergo an approval process by the Central Insecticides Board and Registration Committee (CIB & RC). Consequently, any pesticide legally sold in India must be listed under the schedule of the Insecticides Act, 1968 (DPPQS Act, 1968, 1971).

The Pesticide Management Bill, 2020, was passed by the Union Cabinet of India in February 2020, replacing the Insecticides Act, 1968 (Pesticide Management Bill, 2020). The Bill seeks to regulate the import, manufacture, sale, storage, distribution, and availability of safe pesticide products while minimizing risks to human beings, animals, and the surrounding environment.

VI. CONCLUSION

Seriously affect the biodiversity, various studies showed that it affects physiological, reproductive, and all other processes of the body of aquatic creatures. As a result, it decreases population and also changes the community structure. The ecological balance of any

aquatic ecosystem is harmed by such types of contamination. In aquatic ecosystems, to recover destructed natural habitats, implementation of regulations and continuous monitoring of these natural habitats must be essential, along with international collaboration and avoidance of pesticide contamination.

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