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# The Dreaded Harmful Effects of Pesticides on the Terrestrial and Aquatic life

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## Abstract

Pesticides have long been used to increase the crop yield and make it disease resistant to feed the ever-growing population. However, unchecked and incessant uses of such harmful chemicals have threatened the entire biodiversity by killing the non-target organisms on terrestrial and aquatic landscapes. Also, bioaccumulation and biomagnifications of some non-degradable pesticides have been reported and some of the harmful pesticides like DDT and certain persistent organic pollutants have been banned effectively. The environmentalists and scientists need to find an alternative to replace the use of pesticides and replace them with biodegradable and environment friendly substance which does not kill the non-target organism and an effective agent in increasing the crop yield and make it disease resistant.

***Keywords:*** Pesticides, Mancozeb, aquatic life, water pollution, environment

## Introduction

The growing population of the world and the zest to live a better life caused rapid urbanization and industrialization in the developing and developed countries. This led to shrinkage of the forest cover and the agricultural land that threatened the wildlife and the crop yield, respectively (Azadi et al., 2011). Globally, food scarcity was becoming a threat; hence, to overcome the challenging problem, the food scientists devised chemical formulations in the form of pesticides, bactericides, and fungicides to increase the yield of the crop produce as well as to make it disease resistant. The efforts of the scientists worked out and globally there was acceptance to the use of pesticides, insecticides, weedicides, and fungicides to increase the yield of the crops and make them disease resistant (Carvalho, 2006). Moreover, pesticides were also

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used in household pest control as aerosols, sprays, etc. to control and kill cockroaches, mosquitoes, houseflies, rats, fleas, ticks and many other harmful insects (Lemus and Abdelghani, 2000). The first reported pesticide uses dates back to the Roman empire although the extensive production of pesticides started around the decade 1940–50. The discovery of effective and cheap pesticides like Aldrin, dichlorodiphenyltrichloroethane (DDT), dieldrin, β-benzene hexachloride (BHC), 2, 4-dichlorophenoxyacetic acid (2, 4-D), chlordane and endrin, etc. powered the pesticide industry. Usually, pesticides belong to the major classes of organochlorines, organophosphates, carbamates, pyrethroids, neonicotinoids, and dithiocarbamates. Also, fungicides, captan and glyodin, malathion was introduced between 1950 – 55, which was followed by the discovery of triazine herbicides (Ecobichon, 2001; Hakeem et al., 2016). Interestingly, herbicide, Agent Orange was used as warfare in the Vietnam War to poison the Vietnam veterans (Chamie et al., 2008). Mancozeb (MZB) belongs to the class of dithiocarbamates as MZB is a chelate of ethylene bis-dithiocarbamates (EBDC) with zinc and manganese, as a broad-spectrum fungicide (Belpoggi et al., 2006).

The exhaustive use of these chemicals exerted its ill-effects on the environment affecting the terrestrial and aquatic life; disrupted the ecological balance; and thus, held as a potential threat to the ecosystem. Though, pesticides were effective in controlling food inflation and increasing the crop yield, it was reported to harm the non-target organisms, too drawing the attention of environmentalists and scientists. Moreover, there are certain pesticides which were banned or discontinued due to bioaccumulation in tissues or its lethality to non-target organisms.

## Materials and Methods

### To estimate the water quality

The water quality parameters are essential to establish as it is well known that dissolved oxygen (DO) gets reduced on exposure to pesticide as they are capable of destroying the aquatic flora which are responsible to maintain the DO. The water parameters like temperature, biochemical oxygen demand (BOD), pH, hardness etc will be vital for the reactivity and diffusion in water. The prescribed limits of the water physicochemical parameters as recommended by APHA et al, 2017 is total dissolved solids (TDS) 165 to 185.50 mg/L, hardness 160 to 190 as $CaCO_3$ mg/L, dissolved oxygen (DO) 6.6 to 7.4 mg/L, temperature (T) 22.0 to 28.5$^{o}$C, and pH 6.7 to 7.5.

**To estimate the bioaccumulation of pesticides in water and tissues**

The concentration of pesticides in the water bodies, tissues of plants and animals can be estimated by employing high performance liquid chromatography (HPLC) against a control. The obtained peak will show its concentration; the steeper the peak more will be the concentration of the examined pesticide (Derby et al., 2021).

**To estimate oxidative stress and transcriptomic analysis of the pesticide**

It is well known that pesticides, heavy metals, persistent organic pollutants (POPs), etc. are xenobiotics and will cause oxidative stress in an organism as they are capable to disrupt the antioxidant defense system of the body as they increase the free radicals in the form of reactive oxygen species (ROS) and reactive nitrogen species (RNS). These entities can be dangerous for the body as the cell maintains a reducing type of environment; also, it is vital for the cell to maintain the integrity of disulfide bridges formed between two cysteine amino acids. The transcriptomic analysis of selected genes can give an idea of the changes caused in the mRNA machinery due to the accumulation of xenobiotics (Awasthi et al., 2018; Ratn et al., 2018, 2017; Trivedi et al., 2021).

**Estimation of the lethal concentration for acute, sub-acute, sub-chronic and chronic studies**

Uniform bioassays are performed to calculate the approximate median lethal concentration (96h-$LC_{50}$) till 96 h of the test chemical (APHA, 2017) with some researchers considering the toxicity of 24h to 72h also. The fishes are released in aquariums having different concentrations of the xenobiotics for 96h. The dosage of the toxicant is established according to its toxicity and previous findings. According to the percentage mortality, the toxicity range is assumed either as mg/L or µg/L. Further, to find the accurate concentration with respect to control, the fishes were again released in glass aquaria that had concentration below the calculated dose. The median lethal concentration (96h $LC_{50}$) can be determined by the 'Trimmed Spearman-Karber' method (Hamilton et al., 1977) or 'probit analysis' (Finney, 1971).

Experimental Setup: To perform the desired study to establish the toxicity of any xenobiotics in in-vitro conditions, the fish must be acclimatized to the laboratory conditions. Once the acclimation process is completed, further experiments can be performed by formation of different toxicity groups along with a control. A control group mimics the original conditions and is free of any toxicant. The experimental groups can be prepared by giving a dose of 10% to 50% of the calculated 96h-$LC_{50}$. The experiments should be performed in triplicates and half of

the water in aquaria should be replaced daily to remove the excretory wastes. After replenishment of the water, the concentration of the toxicant should be maintained as before. After anaesthetization by 0.01% (*v/W*) diethyl ether, the fishes will be sacrificed to obtain the desired tissues for detection of oxidative parameters and transcriptomic analysis.

Outcomes of the studies: Mostly, pesticides used for agricultural purpose are polar, water-soluble, and heat stable. Also, the tendency of some pesticides to breakdown into metabolites or byproducts which are more toxic than the parent compound chemical is also worrisome. There are fungicides like Mancozeb which are photolabile. They are not soluble in the water but on exposure to sunlight, the EBDC breaks down in a more toxic byproduct, ethylene thiourea (ETU) and metals like manganese (Mn) and zinc (Zn). Moreover, non-specific pesticides kill non-target plants and animals which are not desired and creates disturbance in the environment. Also, some pests become resistant to the pesticides which do not serve the purpose but harms other organisms. After exhaustive researches on the harmful effects on pesticides, DDT was completely banned in the USA in the year, 1972. Also, India disapproved the use of DDT for various purposes and completely banned its agricultural use in the year, 1989. The list of banned pesticides has been increasing since with an emphasis on POPs. As pesticide toxicity has become a global menace, in 2001, 179 nations signed an international treaty in Stockholm Convention to discontinue the use of twelve POPs, including DDT. There are ample numbers of studies that have reported the harmful and toxic effects of the pesticides affecting the terrestrial and aquatic biodiversity.

**Studies that highlight the threat to the terrestrial ecosystem**

The terrestrial ecosystem comprises of plants and animals that resides on land. An increase in susceptibility of plants to diseases and reduced seed quality was reported on the use of herbicide, glyphosate. Also, herbicides like sulfonylurea, sulfonamide, and imidazolinones had detrimental effects on the productivity of non-target crops, plant communities and wildlife. There are many ecologically important insects like bees and beetles which have declined in areas where carbamates, organophosphates, and pyrethroids were used. Also, formulations of pyrethroids with imidazole are harmful to bees too. The bee foraging activity and learning behavior was compromised on the use of imidacloprid. The use of neonicotinoids completely wiped out the population of bees and amounts of this pesticide as also reported in honey and wax used for human welfare. A constant decline in the populations of honeybees, birds, earthworms, beneficial soil microbes have been reported where pesticides were used. Earthworms play a

significant role in the soil ecosystem by acting as bio-indicators of soil contamination and as models for soil toxicity testing; they also contribute to soil fertility. Rapid declines in the population of bald eagles due to deaths were recorded due to exposure of DDT and its metabolites. Some of the bird species feeds on earthworms but incessant use of fungicides kills these populations. Organophosphates have been reported to kill birds, especially raptors.

To maintain the ecological balance, many different species work together to work out the smooth functioning of the system. The microbial soil population is important in nutrient uptake in plants, breakdown of organic matter thus contribute in soil fertility. The better the soil fertility the better will be the growth of the plants; this can reduce the dependence on the use of pesticides. The process of nitrification, ammonification, and denitrification is an important process as the plants cannot utilize the atmospheric nitrogen directly; instead, the plant absorbs nitrates from the soil fixed by these bacterial populations. Fungicides like glyphosate, chlorothalonil and dinitrophenyl interrupts the nitrification and denitrification processes.

**Studies that highlight the threat to the aquatic ecosystem**

The residues of pesticides reach the aquatic ecosystems via drift, runoff water caused by rain, percolation and leaching through the soil or direct spraying of pesticides to control the mosquito's population. The decrease in the DO level and death of aquatic plants, decaying organic matter, and increase in algal blooms threaten the aquatic life by interference in the physiological and metabolic mechanisms of the fish population. The aquatic animals are exposed to pesticides by direct absorption through skin and gills and by direct consumption of the contaminated water. It is estimated that most of the DO is replenished by the aquatic plants and release of pesticides kill these plants; this results in decline of DO levels leading to suffocation and declined fish population and productivity. The water polluted with different pesticides has even affected the amphibians too. Carbaryl has been found toxic for several amphibian species, whereas, herbicide glyphosate is known to cause high mortality of tadpoles and juvenile frogs (Relyea 2005). Small concentrations of malathion have been shown to change the abundance and composition of plankton and periphyton population that consequently affected the growth of frog tadpoles (Relyea and Hoverman 2008).

Toxicity studies on phorate were reported by Ratn et al., (2017) where they recorded oxidative stress and DNA damage in fish, *Channa punctatus*. Profenofos is toxic to the fish, *Channa punctatus* and induced DNA damage, genotoxicity, and influenced the behavioral patterns (Pandey et al., 2018, 2011a, 2011b). Some pesticides individually and some in

combination can negative impact the growth of the fish by interference with the physiological and molecular mechanisms, thus impacting the fish population (Arisekar et al., 2019; Bhaskar and Mohanty, 2014; Díaz-Barriga et al., 2015; Kavitha and Venkateswara Rao, 2009; Kumar et al., 2010; Kunwar et al., 2021; Slade et al., 2017; Srivastava and Singh, 2013; Tabassum et al., 2016; Tilton et al., 2006). A fungicide, MZB, also exert its ill-effects on fish population. In a study conducted by Costa-Silva et al., (2018), MZB was a potent toxic as there was induction of ROS. MZB has been reported to be a teratogen (Larsson et al., 1976), neurotoxin (Domico et al., 2007), developmental and reproductive inhibitor (Runkle et al., 2017), carcinogen (Tilton et al., 2006), and an agent that can cause oxidative stress that can impair an organism's metabolic balance (Marques et al., 2016). Moreover, MZB was also capable to instigate morphological abnormalities such as body axis distortion, DNA damage, cell death, and changes in behavioral patterns during zebrafish development. Also, it has been observed that on exposure to MZB, the fish also exhibits changes in their behavioral patterns, loss of balance, erratic swimming, sluggish movement, and lethargy (Atchison et al., 1987).

## Conclusion

The incessant and unchecked use of pesticides have impacted and disturbed the entire ecological balance. The pesticides are proven to be harmful for the terrestrial and aquatic flora and fauna. Also, there are studies on negative impacts of pesticides in humans. Some of the pesticides bio-accumulate in the bodies of the organism that ultimately result in death of the concerned organism. It is high time that the conversationalists, environmentalists, and scientists sit together and find a probable solution to the menace of the pesticides. Biodegradable and harmless pesticides are the need of the hour to replace such harmful pesticides.

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