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Review

Excessive Use of Pesticides is a Risk Factor to Fishes: A Review on its Effects and Control Strategies

Nimra Tahir[1], Aadab Akhtar[1], Moazama Batool[1*], Qurat Ul Ain[1]

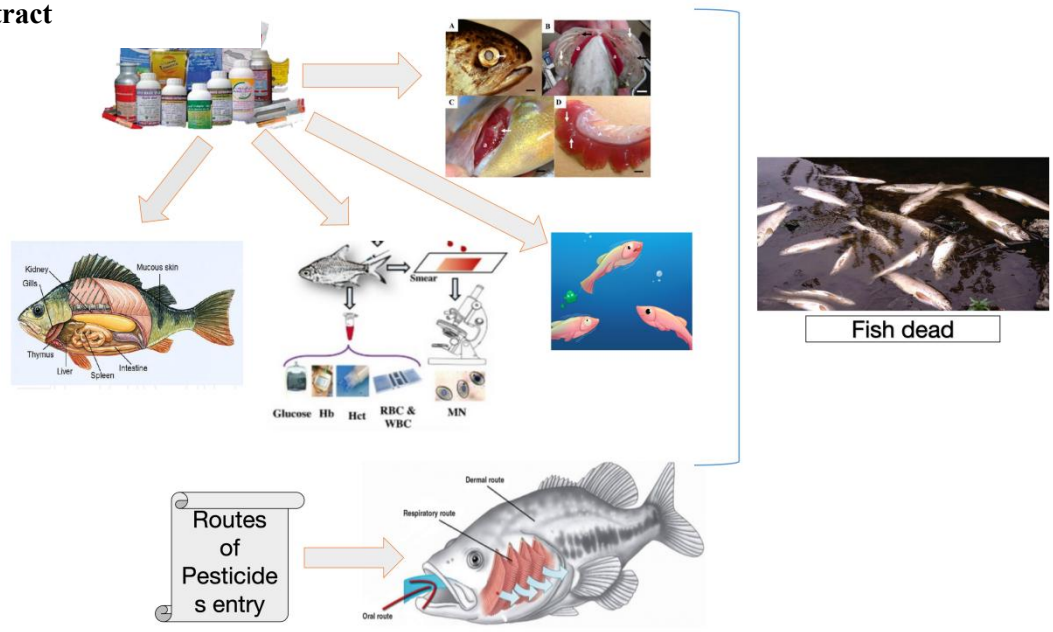
[1]Department of Zoology, GC Women University Sialkot, Pakistan.
*Corresponding author:
moazama.batool@gcwus.edu.pk

Abstract

Pesticides are the chemical compounds, used to kill pests, including insects, rodents, fungi, unwanted plants and possess unique physical and chemical properties. These are classified into various classes on the basis of different characteristics like chemical composition, function and target animals, they kill. These are widely used to control diseases by killing their vectors like mosquitoes and gain high agriculture production. However, these pesticides are also very toxic to many non-targeted animals, especially fish. Uncontrolled and irregular consumption of these chemicals can be responsible for the death of fishes even their sub-lethal concentration can affect their various organ and its functions. Aquatic resources and aquatic animals are precious assets, as they give high productivity and protein yield. Fish contains high level of vitamins and minerals which are essential for normal growth. Aquatic animal and sea food increase national economy by providing employment chances. Use of pesticides is increasing in agriculture, which is disastrous to public health and aquatic ecosystem as well. Pesticides are continuously entering aquatic system, where they accumulate in fishes which are in return eaten by man and in this way they get diseased by pesticides. Therefore there is a need to adopt best management practices to protect water qualities and ultimately fishes.

Keywords: Aquatic, chemicals, ecosystem, pesticides, rohu, thaila

Graphical Abstract



1. Introduction

Pesticide is a chemical substance used to prevent, destroy, repel or minimizing the effect of pests [1].Pest can be insects, plant pathogens, weeds, mollusks, birds, mammals, fish, nematodes (roundworms) and microbes. The most common used pesticides include insecticides, herbicides, fungicides and rodenticides, and other less well-known pesticides comprise of growth regulators, plant defoliants, surface disinfectants and some swimming pool chemicals. Most commonly, pesticides are used in health sector and agricultural crops [2]. In present era of green revolution the human population is increasing swiftly. Forests have been utilized for habitation, disturbing environmental balance [3]. We are also facing the most emerging problem of pollution having diverse variety of pollutants [4]. These pollutants include domestic wastes, untreated effluents from industries, chemicals like pesticides used in agriculture, organic compounds and heavy metals [5, 6, 7, 8, 9].

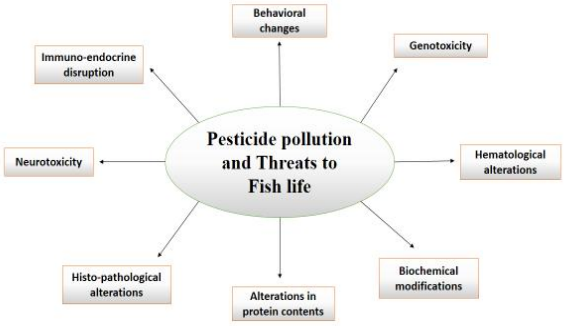


Figure 1. Various effects of pesticides on fishes.

These pollutants change the water quality which is the habitat of all aquatic organisms [10], which may cause the death of fish in acute concentrations [11, 12]. Aquatic animals are very important to humans specially fishes because they provide food to them [13]. Pesticides may accumulate in fishes directly through gills or skin which is called bioconcentration, through ingestion of suspended particles or through ingestion of contaminated food (biomagnification). The result of these pesticides alter the behavior of fishes including alteration of swimming patterns and their sluggish movement. Immune system of fishes also affected by low concentration of fishes. Exposure with endosulfan reduces the protein levels in intestine, blood, gills, liver and muscles of spotted snakehead (*channa punctatus).*Deficiency in development and growth ultimately affect the survival rate of fishes [1]. Whereas in low concentration leads to their bio accumulation and ultimately effects human beings through food web [14, 15]. This is a serious issue that should be treated and focused properly to ensure the safe fish usage [16, 17]. To determine the effects of pesticides on aquatic organisms different biological methods are used like *in situ* bioassay [18, 19, 20, 21, 22]. Sometimes water cages are also used to hold fish in water column when water column is too deep or too fast [23].

2. Classification of pesticides

Pesticide includes herbicides, insecticides, fungicides, rodenticides, garden chemicals and household disinfectants used to control or protect pests [24]. They varies in their physical and chemical nature. So they should classify according to their properties. There are three main modes of their classification [25].

1. Classification on the basis of mode of entry [25]
2. Classification on the basis of chemical composition of pesticides [25]
3. Classification on the basis of their function and the pest, they kill [25].

3. Classification on the basis of mode of entry

The pathways through which pesticides come in contact with their target are called modes of entry. These include the following:

3.1. Systemic pesticides:

These are the pesticides absorbed by animals and plants and are transferred to untreated tissues. Systemic herbicides move in plant body and effect the untreated leaves, roots and stem. They enter plant tissue and kill specific pest by moving through the vascular bundles. Movement of systemic pesticides may be unidirectional or multidirectional. Examples include glyphosate, 2, 4-Dichlorophenoxyacetic acid [26].

a) **Non systemic pesticides**

These are also known as contact pesticides as they kill target pests when they are in contact with them. Physical contact between pest and pesticide is mandatory to get best results.

They enter into body of pest by epidermis and kill them by poisoning. Examples are paraquat and diquat dibromide [26].

b) **Repellent**

They do not kill pests but are strong enough to protect the treated areas from pests and are also able to interfere with the ability of pest to locate crop. Common insect repellents are Benzaldehyde, used for bees. Other examples are dimethyl carbate, dimethyl phthalate and metofluthrin [26].

c) **Fumigants**

These pesticides kill the pests by producing vapors and enter in pest's body through trachea and kill them by poisoning. They are used to destroy stored pests from fruits, vegetables and grains. They are also used to treat nursery stock including hydrogen cyanide, naphthalene, nicotine and methyl bromide. Common soil fumigants are nematicides as methyl bromide, dichloropropane and propylene oxide [26].

4. Classification on the basis of chemical composition of pesticides

Pesticides are classified into Organochlorine, organ phosphorus, Carbamates, pyrethrins and pyrethroids based on their composition. This method determines the efficiency, physical and chemical properties of pesticides. They are may be synthetic and natural (plant origin) [26].

4.1. Organochlorine

These are organic compounds with five or more chlorine atoms and are used in agriculture and public health. They affect the nervous system of the insects leading to convulsions and paralysis and result in their death. Examples include DDT, endosulfan, lindane, aldrin and chlordane. Although the production of DDT is banned but still it is used in tropical countries for vector (mosquito) control [26].

4.2. Organophosphates

These are broad spectrum pesticides used to control wide range of pests due to their multiple functioning. Stomach poison, contact poison, fumigant poison leading to nerve poison are the characteristics of organophosphates. They cause less environmental pollution so they are biodegradable. Examples include diaznon, parathion, Malathion and glyphosate [27].

4.3. Carbamates

They are structurally similar to organophosphates but they have different origin. Carbamates are derived from carbamic acid whereas organophosphates are produced from phosphoric acid, while. Both have same working principle to affect the transfer of nerve signal and lead to the death of pest by poisoning. Most common insecticides under this group are carbaryl, amino carb and carbofuran [25].

4.4. Synthetic pyrethroids

These are organic pesticides prepared by duplicating the structure of natural pyrethrins and are more stable with long residual effect than natural pyrethrins. The major components are pyrethrins 1 and pyrethrins 2 and small amount of related cinerins and jasmolins. They are more toxic to insects and fish as compared with mammals and birds. Cypermethrin and permethrin are common examples [57].

5. Classification on the basis of function of pesticides and pest organism they kill:

In this group, pesticides are named specifically according to their activity. The name of these pesticides is derived by a Latin word *Cide* means kill or killer, used as suffix after the name of target pest.

Some are named on the basis of their functions like growth regulators that increase or decrease the growth of pests; defoliants which causes the plants to drop their leaves; repellents, which repel the pests; attractants, which attract pests usually to a trap [27].

5.1. Occurrence of pesticides in aquatic ecosystem:

Pesticides used different ways to enter in water bodies, that is determined by the identification of three main routes [28, 29]. These routes include water column, organic site of attachment like mosses, algae, branches and vascular hydrophytes and inorganic sites of attachments like sedimentary materials [8].

5.2. Determination of pesticide's contents:

In sediments, water, organic substrate and especially in plants or animals tissues pesticides can be determined by using chemicals [30]. First of all the solid animal or plant tissue is ---

Table 1. Types of pesticides [31].

Types of pesticides	Target pests\Function	Examples
Insecticide	It Kills insects and arthropods.	Aldicarb
Fungicide	It is used to control fungi, molds and rusts.	Azoxystorbin
Bactericide	It is used against bacteria.	Copper complexes
Herbicide	It acts against weeds and unwanted plants.	Atrazine
Pisicide	It is used against fishes.	Rotenone
Lampricide	It acts against the larvae of lampreys, jawless fishes.	Nitro phenol Trifluromethyl
Virucide	It is used to kill viruses.	Seytovirin
Nematicide	It is used to kill nematodes that are the parasites of plants.	Aldicarb
Algaecide	It acts against algae.	Copper sulfate
Termticide	It kills termites.	Fipronil

Table 2. LC50 values of some pesticides for different fish species.

Serial.no	Pesticides	Test organism	Exposure time	LC50 value	References
1	Acephate	*Pimephales promelas*	96 hours	>1000 mg/L	Johnson and Finely, 1980
2	Alaclor	*Salmo gairdner*	96 hours	2.4 mg/L	Johnson and Finely, 1980
3	Diaznon	*Channa punctatus*	96 hours	3.09 ppm	Rahman et al., 2002
4	Elsan	*Channa punctatus*	48 hours	0.43 ppm	Rao at el., 1985
5	Endosulfan	*Catla catla*	96 hours	0.98 mg/L	Ilyas and javed,2013

homogenized then they are extracted by acetone, after it evaporation is done into small volumes. At the end cleaning and drying is done and finally sample is analyzed [16, 32, 33, 34, 35].

5.3. Effect of pesticides on Fishes

5.3.1. Indirect effects of pesticides on fishes

Pesticides are continuously reducing the organisms which are important for the survival of fish [36]. They affect indirectly by reducing its food sources [37]. It also reduces the stability of fish's habitat and increases the chances of predation for fish [22, 38].

5.3.2. Direct effects of pesticides on fishes

In addition to indirect effect pesticides also effect fish directly [22]. They cause different types of toxicity in fishes leading to the change in their behavior [9, 13, 39, 40, 41, 42]. They also induce changes in their hematology [41, 43]. Pesticides also disturb the histopathology of fishes [20, 44, 45]. They are also responsible for biochemical changes and disturb the endocrine system of fish [46, 47, 48]. They also result in the change of acetyl cholinesterase's activity [7, 9, 49, 50]. Different fish species are susceptible to different amounts of pesticides. The changes result due to response of pesticides vary from one part of fish's body to the other one. And these changes are mostly observed all over the body parts of the fish [50].

5.3.3. Lethal effects of pesticides on Fish:

Sub lethal amounts of some pesticides result in abortion of fish. In 1996, in Bear Creek, a branch of Rouge River high rate of mortality of different fishes was studied including 92,000 steel head, 19 rainbow trout, 114 juveniles of salmon and thousands of non-games fishes due to pesticides [24]. Small amount of Methyl parathion including 4.8ppm, 8ppm and 10ppm caused 50%, 80% and 100% deaths of Thaila (*Catla catla).* Dimethotate and Lambda-cyhalothrin are proved to be lethal for Rohu (*Labeo rohita)* [10, 46]. Table 2 showing common pesticides with their lethal concentrations for different fishes. Sub lethal concentrations of these pesticides result in biological changes in fish and decrease their survival rates [40]. Lethal concentration of DDT results in greater disturbance in the reproductive behavior of various species while some species like cutthroat goldfish do not show any change in their reproductive pattern [51]. The variations occur due to pesticides are divided into hematological, behavioral, protein level, endocrinology, immunity and biochemical changes of fish.

5.3.4. Effect of pesticides on Fish's hematology:

Pesticides like DDT, Endosulfan, BHC, Aldrin, Chlordane, Karate, Dimelthrin and Sulfan effect the hematology of fish like changes the haemoglobin level, WBCs and RBCs level in different fishes like *Cyprinus carpio* [52], *Oreochromis mossabicus* due to potassium chlorate and potassium dichromate [53] and lead [54]. *Channa punctatus* [51] is effected by endosulfan. The hemopoietic system becomes chronic in *Labeo rohita* due to chlordane. Many other studies were made to study the effect of pesticides on the haemotology fish [55].

5.3.5. Effect of pesticides on Fish's behavior:

Pesticides have variety of effects on fish including change in their ability to swim due to which they can be easily preyed by predators. They also lower their feeding and fish also becomes unable to protect its territories [56]. They also affect their school behaviour [38]. Pesticides also affect their immune system due to which their level of infections and diseases increases [48, 52]. In *Catla catla* methyl parathion changes the body coloration, loss of equilibrium, jerk movement and increased movement of operculum. Pesticdes also effect the migratory behaviour of fish, disturbing the life cycle of fish like these pesticides effect the migration of salmon fish from fresh ecosystem to marine ecosystem [52]. Sodium cyanide results in various behavioural changes like imbalance swimming, arbitray movement of body and excitability in *Catla catla, Labeo rohita, Cirrhinus mrigala* and *Cyprinus carpio* [39].

5.3.6. Effect of pesticides on biochemical activities of fish:

Many studies have done to show the effect of pesticides on the biochemical activities of fish [50]. These changes are tissue specific and have been studied in lungs, gills, kidneys, brain and body viscera and their results differ from organ to organ and specie to specie like peroxidase activity was studied in brain, viscera and muscles of tilapia but gill was the organ in which high level of changes was observed [57]. Organophosphates with sub lethal concentration are also responsible for changes in the enzymes such as glutaminase in brain, responsible for the movement of various brain parts in *Labeo rohita* [58]. Endosulfan subordinated the level of activities of citrate synthase and glucose 6 phosphate dehydrogenase in skeletal muscle, liver and brain of *Clarius batrachus* [41]. Cypermethrin caused changes in the enzymes including catalase, Glutathion reductase and peroxidase in tissues of brain and muscles of *Tor putitora* [59].

5.3.7. Effect of pesticides on protein level of fish:

Pesticides have adverse effects on protein level of fishes, like nickel lowers protein level in *Heteropneustes fossilis* [56], phenyl mercuric acetate reduces protein level in muscles and liver of *Channa puntatus* [60]. Karate decreases protein level in *Cyprinus carpio* [11]. Exposure of Thiamethoxan resulted in significant decrease in the total protein content of liver in *Oreochromis niloticus* [49], while exposure of thiodonn effected the level of protein content of liver of *Clarias gariepinus* [57]. While lethal concentration of monocrotrophs resulted in decreased level of carbohydrates, proteins and lipids in *Labeo rohita* [61]. There are many pesticides like Dioxin that effects the pathway of genes how they control the synthesis of proteins like vitellogenin which is responsible for

egg development [17].

5.3.8. Effect of pesticides on immunology and endocrinology of fish

Pesticides have adverse effect on the immune system of fish, which results in fish diseases and eventually leading to their death. Pesticides are also harmful for fish endocrine system. During initial development there are higher chances of damage of fish's endocrine system. Pesticides are also act as sex hormone blocker resulting in abnormal sex development, irregular sex ratios and also disturb their mating behaviour. Many environmental chemicals are also harmful for fishes as they disturb the level of thyroid hormone [5].

How to reduce the effect of pesticides:

I. Use of pesticides only on the time of need, excessive use should be avoided.
II. Pesticides with less toxicity should use.
III. Pesticides should be used in safe and proper way [61].

Selection of pesticides:

IV. Pesticides that are selected should have less acute toxicity.
V. Application of pesticides should be restricted in an area with greater water supply.
VI. Pesticides should be applied when soil conditions are very high.
VII. Pesticides should have soil absorption, short life time and low water solubility.
VIII. v. Pesticides should have low water runoff [61].

Best management practices to protect aquatic life:

IX. Adopt an Integrated Pest Management (IPM) to use the least amount and least toxic of pesticides for pest control. Before application of pesticides be sure that it is needed and can be accomplished safely and effectively.
X. Determine the chemical control options. Select that option which has least negative effects on water and aquatic organisms including fishes, chemicals (Pesticides) selected for use should be less toxic to fish and other aquatic organisms.
XI. Read and follow all the directions that are labelled. Use pesticides only as directed, proper care and attention is needed during applying, methods and rates. Control the rate, method timing and types of pesticides being applied. Pesticides label directions are not advice, they are legal requirements.
XII. Be careful during mixing and loading of pesticides, be sure that the equipment is working and is properly calibrated. Mix and prepare only the amount of pesticide that is required for immediate application.
XIII. Apply pesticide at proper time consider the time, weather and life cycle of pest when planning application.
XIV. Store pesticides in a ventilated, well lighted, and secure area from flooding.
XV. Dispose of empty containers and rinse water properly.
XVI. Keep record of all pesticide use, records will allow low evaluation of pest control efforts and help to plan future treatments [61].

6. Conclusion

This review paper contains literature of pesticides including their classification on the basis of their chemical composition, their mode of entry and nature of target pest they kill. Pesticides may be organic or inorganic in nature. Their inappropriate use may affect all biological level and all components of environment. Sometime this effect may be global or local, permanent or temporary. In addition to terrestrial organism they adversely affect the aquatic organisms including fish. Pesticides are becoming major source of economic loss by declining the number of fishes and also making them harmful for man consumption. And this unhealthy fish can cause health hazards for those who used these fish. Necessary precautionary measures should take during selection of fish. Care should also take during selection of pesticides they should be less toxic. Because the toxicity of pesticides bring changes in fishes, they affect their heamotlogy, behaviour, protein and lipid level, biochemical activities, life cycle, enzymatic activities, physiology and reproduction. So toxic pesticides should avoid to protect water quality and aquatic organisms. Effect of pesticides varies from specie to specie and different fish species are susceptible to different amounts of pesticides, fish that is less susceptible to these

pesticides should use in aquatic system. And best management practices should adopt for betterment of water bodies. In this way national economy can also be increase by protecting aquatic life as aquatic animals and sea food are the great source to improve national economy. All chemicals including pesticides should be carried out to laboratory, it will be helpful to determine their toxicity by experimentation. In this way nontoxic or less toxic pesticides can be use.

Data Availability statement

The data supported in this study are available on request from the corresponding author.

Conflicts of Interest

All authors declare that, they have no conflict of interest.

Author Contributions

All authors help in equally contributed in this work.

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