



Indian major carp *Labeo rohita* (Hamilton, 1882) toxicology approaches on overview

Jayakumar V, Senthilmurugan S, Vijayan P, Tamizhazhagan V

Department of Zoology, Annamalai University, Tamil Nadu, India

Abstract

Indian major carp *Labeo rohita* is used for the various toxicology experiments in life science and medicine field to be consumed major food sources and highly rich proteins present in the Indian major carp. Many toxicology approaches made in lower animals used to toxicants like herbicide, pesticide, insecticide heavy metals etc., Behavior studies, hematology studies, enzyme studies, recovery studies, histology studies, immunological studies, etc., this amassed data may be helpful for the researchers to attention on the significant areas of research yet to be revealed. Widespread information about the animal has been together from various sources like books, Journals and authentic classical texts, etc. Researcher and pharmacologist and toxicological treatment may be helpful security of the whole fish was settled in the criticism.

Keywords: behavior studies, hematology studies, enzyme studies, recovery studies, histology studies, immunological studies

Introduction

Water pollution is usually caused by various human sources, typically (point and non-point) industrial facilities and agrochemicals especially in aquatic ecosystem, has grown up to be a serious environmental problem nowadays. Adversely human activities are directly or indirectly affect the environment. Developed and developing which are progressing rapidly in the field of agriculture, technology and industries are continuously releasing numerous kinds of harmful substances into the biosphere and thereby causing a severe threat to the environment (V Tamizhazhagan & Pugazhendy, 2016b) ^[97]. Pesticides are commonly used in modern agriculture to aid in the production of high quality food. However, some pesticides have the opportunity to cause serious health and environmental damage (V Tamizhazhagan & Pugazhendy, 2015) ^[77, 95]. These agrochemicals and industrial discharges may carry away effectively by rain, wind, rivers and floods into the large water bodies and change their physico-chemical properties (V Tamizhazhagan & Pugazhendy, 2016a; Vijayan, Senthilmurugan, Pugazhendy, & Tamizhazhagan, 2018) ^[96] with extreme toxicity. The water contamination cause damages to aquatic life especially to fishes which are very sensitive to wide range of toxicant in the water (Herger *et al.*, 2008) ^[91]

The industrial development and rapid urbanization have led to development of polluted zones discharging potentially toxic compounds in the environment. Especially, indiscriminate use of pesticides resulted in contamination of aquatic system has now become a global problem and is being extensively researched worldwide (V Tamizhazhagan & Pugazhendy, 2016b) ^[97]. The pollution of environment due to use of pesticides has become an increasing problem over the last century with the development of industry, agriculture and increase in population (Pugazhendy, Revathi, Prabakaran, Murugan, & Hwang, 2008) ^[92]. Aquatic water bodies are frequently adulterated with a multiple of potentially hazardous

substance (Cattaglin and Fairchild 2002) ^[17]. Pesticide poisoning is part of the main causes of morbidity and mortality in developing states. Now a day's farmers are using the verity of pesticide, insecticide, herbicide using agricultural field and seed germination (Senthilmurugan, Sattanathan, Vijayan, & Tamizhazhagan, 2018) ^[93] Pesticides are generally used in contemporary agriculture to aid in the manufacture of high quality food (Vairakkannu Tamizhazhagan, 2017). The pesticide is mainly two type's organochlorine and organophosphate in recent year monocrotophos are organophosphate using their field of controlling the insect pest (V Tamizhazhagan & Pugazhendy, 2015) ^[77, 95]. The majority of these poisonings occur in developing countries where less protection against exposure is made. Knowledge of health risk and safety use is limited or even unknown (Jayalakshmi *et al.*, 2017) ^[36]. Organophosphates are most preferred insecticides in agriculture due to their effectiveness, less persistent life and easy detoxification in animal tissues which directly inhibit AchE (Acetylcholinesterase) activity alkaline phosphate and acid phase were both cell were gradually decreased observed by in fish and other aquatic organism (Vairakkannu Tamizhazhagan, 2017). Fishes (Fig No1) are widely used to evaluate the health of aquatic ecosystems because pollutants build up in the food chain and are responsible for adverse effects and death in the aquatic systems (Usha *et al.*, 2017) ^[81]. The random use of different pesticides often causes a lot of damage to non-target organism. Organophosphate pesticides constitute a large proportion of the total synthetic chemicals employed for the control of pests in the field of agriculture, veterinary practices and public health (Padmapriya *et al.*, 2017) ^[59].

Pesticides are well established as an efficient approach to control pests. At the same time of such chemicals are highly toxic to other species in the environment (Tamizhazhagan, 2015) ^[77, 95]. Recent studies have proved that extremely low quantities of pesticides which enter the aquatic environment

can affect productivity of organisms to kill eggs and larvae. The contaminations affect all groups of organisms in an aquatic ecosystem like invertebrate (Meenambal and Pugazhendy 2012) [48]. The heavy metal and pesticide contamination of aquatic system has attracted attention of researchers to all over the world and has increased in the last decades due to extensive use of them in agricultural, chemical and industrial processes that are becoming threats to living organisms (Dutta and Dalal, 2008) [24]. Highly reactive electrophilic components can be removed they covalently bind to tissue nucleophilic compounds which would be translated into the toxic effects. Acid phosphatase on the other hand is a phosphatase which frees attached phosphate groups from other molecules during digestion. It is a lysosome, hydrolytic enzyme with an acid pH optimum. It takes part in the dissolution of dead cells and as such serve as a good indicator of stress condition in the biological system (Viran *et al.*, 2003) [85].

In humans and experimental animals significant accumulation of lead acetate in the blood and tissues occur following environmental exposure (Areola *et al.*, 1999) [10]. Lead acetate poisoning is the most significant environmental health problem children may appear inattentive, hyperactive and irritable even at minimal lead acetate exposure. Children with greater lead acetate levels may be assigned with delayed growth, decreased intelligence, Short-term memory and hearing loss. At higher levels, lead acetate can cause permanent brain damage and even death (Cleveland *et al.*, 1999). To boost antioxidant levels, food is always favored over supplements mainly because it contains thousands of antioxidants, in contrast to supplements, which are generally rich in a single or a few antioxidants (Pichaimani *et al.*, 2017) [60]. Aquatic ecosystems that run through agricultural areas have a high probability of being contaminated by runoff and ground water is available from a variety of chemicals. Highly effective pesticides are used tremendously, which are entering the aquatic environment bring multiple changes in organism by altering the growth rate, nutritional value, behavioral pattern, etc (Pugazhendy *et al.*, 2008) [61, 62]. The ultimate reviews have updated toxicology approaches knowledge and present scenario researchers and environmental biologist helpful to focus on water pollution controlled pollution help this review this document related to human health disease pin point monitors all related filed (Tabel No.1).



Fig 1: Morphological structure of Indian major *Labeo rohita*

Toxicology approaches

Behavior is considered a promising tool in ecotoxicology (Drummond and Russom, 1990; Cohn and MacPhail, 1996) [23, 19] and these studies are becoming prominent in toxicity

assessments in unicellular organisms (Tadehl and Häder, 2001) [73], insects (Jensen *et al.*, 1997) [37] and fish (Little and Finger, 1990). Most physiologic and environmental changes can induce variations in fish behavior (Israeli-Weinstein and Kimmel, 1998; Almazán-Rueda *et al.*, 2004) [33, 7]. Behavioral characteristics are obviously sensitive indicators of toxicant's effect. It is necessary, however, to select behavioral indices of monitoring that relate to the organisms behavior in the field in order to derive a more accurate assessment of the hazards that a contaminant may pose in natural system The migration of the fish to the bottom of the tank following the addition of cypermethrin clearly indicates the avoidance behaviour of the fish, which was reported (Murthy, 1987) [50]. Dermal acute toxicity tests represent an important method for establishing criteria to evaluate water quality and therein to protect the aquatic environments (NAS/NAE, 1972) [52]. Acute toxicity studies are generally employed to compare the sensitivities of different species to different potency of the chemicals and to derive, by using LC50 values, ecological concentration of chemicals which could be considered 'safe'.

Table: 1 scientific classification of *Labeo rohita*

| | |
|-----------|-----------------|
| Kingdom | Animalia |
| Phylum | Chordata |
| Class | Actinopterygii |
| Order | Cyniformes |
| Family | Cyprinidae |
| Subfamily | Labeoninae |
| Genus | Labeo |
| Species | <i>L.rohita</i> |

Toxicity data for a variety of pesticides such as organophosphate, organ chlorine, carbamide and pyrethroid pesticides have been reported for number of fish species by various authors (Anees, 1975; Arunachalam and Palanichamy 1982; Arunachalam *et al.*, 1980; Baskaran *et al.*, 1989; Roy and Dutta Munshi, 1988; Singh *et al.*, 1981; Malla Reddy and Basha Mohideen, 1989; Gurusamy and Ramdoss, 2000; Sapna Shrivastava, 2002; Nishar Shailkh and Yeragi, 2004 and Visvanthan *et al.*, 2009) [8, 11-13, 64, 69, 47, 29, 67, 54]. Variations in LC50 if any, under altered energy balance should reflect on the nutritional status of the animal. This would be used to assess the productivity of the aquatic medium concerned and to take appropriate corrective measures. Acute toxicity tests have been historically played a major role in assessing the effect of human activities on animals and such tests have wide applicability in evaluating the toxicity of various types and mixture of pollutant in fish and other aquatic species (Craddock, 1977) [21]. The parameters of short-term (toxicity) exposure are the most common measures of toxicity (Cowell *et al.*, 1972; Krebs and Burns, 1977) [20, 39]. The importance of potential damage to aquatic ecology by effluent has been advocated and demonstrated (Sprague, 1969) [70], informing through various toxicity tests used in the management of water pollution as, to estimate environmental effect of waste, to compare the toxicity of different toxicants in animal, to regulate the amount of discharge pollutant (Buikema *et al.*, 1982) [15].

The hexavalent chromium when present in excess amount induces toxic effects in the cells (Sugiyama,1992) [46] like

genotoxicity (O'Brien *et al.*, 2001; Matsumoto *et al.*, 2004 and oxidative damage Slaninova *et al.*, 2014; Patil and David, 2013; Lushchak *et al.*, 2008) [66, 2, 82, 56]. Oxidative damage primarily occurs through production of reactive oxygen species (ROS) and can damage lipids, proteins, and DNA contributing to loss of activity and structural integrity of enzymes and may activate inflammatory processes (Barzilai and Yamamoto, 2004) [1]. In most cases, the abnormal generation of ROS, which can result in significant damage to cell structure, is considered as an important signal of oxidative damage (Das *et al.*, 2014). Oxidative stress is induced as a result of the three factors: (a) an increase in oxidant generation, (b) a decrease in antioxidant protection, and (c) failure to repair oxidative damage (Velma and Tchounwou, 2010) [83]. Superoxide (O⁻²), one of the parental forms of intracellular ROS, is a very reactive molecule, but it can be converted to H₂O₂ by superoxide dismutase (SOD) and then to oxygen and water by several enzymes including catalase (CAT) and glutathione reductase (GR). Therefore, examining the change in activity of antioxidant enzymes such as SOD, CAT, and GR shall be an effectual method of denoting oxidative stress and changes in their activity and other biomarkers could be the possible tools in aquatic toxicological research.

Aquatic ecosystem of animals

The evaluation of toxic effects of metals in terrestrial and aquatic ecosystems is one of the imperative areas of ongoing research and there is an emergent concern on the development of technique for detection of toxic effects in aquatic animals (Karadede, 2000) [30]. Fishes are an important source of human diet and numerous studies have been carried out on metal pollution in different edible fish species (Erdoğrul and Ayfer, 2006; Ashraf *et al.*, 2012) [55, 45]. Industrial effluents, agricultural runoffs, transport, burning of fossil fuel, and domestic wastes append to the heavy metal in the water bodies owing to their easy uptake into the food chain and bioaccumulation processes. The toxic effects of heavy metals have been examined, including bioaccumulation (Sultana and Rao, 1998) [63] and the instance of metal accumulation in fish tissues can be utilized as effective indicators of environmental contamination (Vutukuru, 2003.) [65]. Many authors have advocated using the oxidative biomarkers in assessing the health of aquatic life (Nussey, 2000) [28] and more in depth studies are necessary for an exact cause effect relationship. Therefore, to study the effectiveness of this way, a laboratory study was conducted in the fish *Labeo rohita* as a function of heavy metal chromium.

Aquatic pollution of pesticide

The rationale of this research is to study the chromium induced oxidative stress along with some biometric assays and to quantify the accumulation of chromium in different tissues of *Labeo rohita*, a most common edible carp fish, and correlate the concentration of metals with respect to their toxic effects on various fish species. The acquired information would further help in the formulation of strategies for treating chromium polluted water bodies and making the river water safe for survival of aquatic life. The potential harmful chemicals or substances such as heavy metals, pesticides and hydrocarbons are dumped either or released into the water

bodies (Ullah *et al.*, 2014) [80]. When these pollutants flow into water bodies in higher concentration than permissible limits when these results in the form of heavy mortality of all life forms residing in those aquatic systems such as fish and shell fish etc. while in lower concentration these lead to bioaccumulation of these pollutants and ultimately go through the food web to human beings (Xie *et al.*, 1996; Morel *et al.*, 1998; Abedi *et al.*, 2013) [88, 49, 3]. This issue is attention seeking and should be treated and focused properly and attentively in order to ensure safer fish consumption on priority basis (Yousaf *et al.*, 2013; Ullah *et al.*, 2014) [89, 80].

Organophosphates like dichlorvos are highly toxic to fish and other non-target aquatic organisms and are powerful nerve poisons, since they inhibit AChE activity in the nervous system by blocking synaptic transmission in cholinergic neurons with disruption of the nerve function causing parasympathetic disorders and death of the organism (Nguyen *et al.*, 2008). Fishes are the most important inhabitants of the aquatic ecosystems which are more frequently exposed to and affected by these toxic pesticides (Scott and Sloman, 2004) [68], because it is believed that regardless of where the pollution occurs, it will eventually end up in the aquatic environment (Firat *et al.*, 2011) [27]. Pesticides can accumulate in fish and affect human health to via ecological cycling and biological magnification (Chebbi and David, 2011) [18]. Ecotoxicological investigations are required to determine the toxicity and potential risk of these toxic chemicals utilizing various biomarkers in fish for monitoring the quality of the aquatic environment thereby health of organisms inhabiting those aquatic ecosystems. Against this background, the present review was aimed at various ecotoxicological aspects of dichlorvos reported in fish including behavioural, histopathological (Tamizhazhagan *et al.*, 2016) [75, 78, 79], haematological (Tamizhazhagan, 2015) [77, 95], biochemical alterations (Tamizhazhagan *et al.*, 2016) [75, 78, 79] and other toxic effects. As a consequence of human activities like mining, improper waste disposal and fuel combustion, our environment is becoming more and more contaminated with toxic heavy metals.

The aquatic environment receives wastes and might be the ultimate depository for these anthropogenically remobilized heavy metals (Olsson *et al.*, 1998) [57, 58]. Heavy metals are characterized as metallic elements that have a relatively higher density in contrast to water Fergusson (1990) [25]. They are likewise regarded as trace elements Kabata-Pendia 2001 [38]. Various factors enhance their detrimental effect and may involve the age of a particular species, sex of an individual, the concentration of dose, route of exposure as well as various biological and physiological adaptations performs an essential part (Verkleji, 1993) [84]. On account of their high level of toxicity chromium, lead, mercury, arsenic and cadmium, rank among the priority metals that are of particular health significance. These metallic elements are viewed as systemic toxicants that are known to incite numerous organ damages, even at lower levels of exposure (Olsson *et al.*, 1998) [57, 58]. Heavyweight metal influence cellular organelles and various enzymes involved in the metabolic process, detoxification, and damage repair (Wang and Shi, 2001) [87]. Metal ions also destroy DNA molecule and nuclear proteins that may possibly lead to carcinogenesis or apoptosis (Beyersmann and Hartwig,

2008) [14] Heavy metals are environmentally present everywhere, readily get dissolved in water and are the major persistent element in the aquatic ecosystem. The major component of most aquatic habitats is fish and they are considered as bio-indicator of heavy metal levels in aquatic environment (Alinnor and Obiji, 2010; Tabinda *et al.*, 2013) [6, 72]. The fresh water ecosystem occupies an extremely small area in comparison to marine ecosystem. Fresh water resources now a day's degraded at a very large scale, due to water pollution (Ahmed *et al.*, 2011) [5]. Developing countries are tackling the problem of water pollution due to the rapid spread of industrialization and civilization. These industries produce a large amount of polluting products especially heavy metals that are constantly drained untreated into nearby rivers. The impact of heavy metals on water ecosystem has turned out to be a global concern (Yousafzai *et al.*, 2008) [90]. Although toxicants impair the metabolic and physiological activities of the organisms, physiological studies alone do not comply with the complete understanding of pathological conditions of tissues under toxic stress. Hence it is advantageous if an insight into histological analysis. The extent of severity of tissue damage is a consequence of the concentration of toxicant and is time dependent. Also the severity of damage depends on the toxic potentiality of a particular compound or pesticide accumulated in the tissues the organisms developed a protective defense against the deleterious effects of essential and inessential heavy metals and other xenobiotics that produce degenerative changes like oxidative stress in the body (Abou EL-Naga *et al.*, 2005; Filipovic and Raspor, 2003) [4, 26].

A variety of contaminants including toxic heavy metals (cadmium, copper, mercury and zinc) is said to be ubiquitously present in rivers, reservoirs and are disadvantageous for aquatic organisms (Olsson, 1998) [57, 58]. In general, they are not biodegrade and therefore, their bioaccumulation in fish, oyster, mussels, sediment and other components of aquatic ecosystems have been recorded from all over the world. It appears that problem of heavy metals accumulation in aquatic organisms including fish needs continuous monitoring and surveillance owing to biomagnifying potential of toxic metals in human food chain (Das and Kaviraj, 2000; Laxi, 2005; Jayakumar and Paul, 2006; Kumar *et al.*, 2007; Kumar *et al.*, 2008) [22, 43, 35, 40, 42]. Environmental protection has attracted the attention of the inclusive cross-section of people all over the world which has now become a global issue amongst scientists and researchers working in this area. Unfortunately several toxic pollutants, few are even unknown or un-identified to the biota, are being regularly introduced in large quantities into the environment, especially into the aquatic environment. Pollution of water by pesticides is an essential dimension of ecological degradation. The disposal of industrial and agricultural wastes directly into the aquatic medium burdens the ecosystem and emphasises the need to analyze, the concentration of these substances in the medium as well as in the organisms. It estimates that approximately 3000000 people are exposed to the effects of organophosphates or carbamates every year worldwide, which leads to up to 300000 deaths (Nagaraju Bantu and Rathnamma vakita, 2013) [51]. Pesticides are also available to be highly toxic not only to fish but also to other organisms which

constitute food for the fish.

Conclusion

Labeo rohita is used as an important toxicology approaches to provide significant results in the scientific field to help to monitor aquatic lower animal to higher animals. In the food chain to relate to human. To help the voracious studies formulate new ideas and innovative of common people may be using this review approach.

Acknowledgement

The authors are thankful to authorities Department of Zoology, Annamalai University, for the facilities provided to carry out this research work.

References

1. Barzilai A, Yamamoto KI. DNA damage responses to oxidative stress, *DNA Repair*. 2004; 3:8-9, 1109-1115.
2. Slaninova A, Helena M. Hostovsky *et al.* Effects of subchronic exposure to N,N-Diethyl-m- toluamide on selected biomarkers in common carp (*Cyprinus carpio* L.), *BioMed Research International*, Article ID 828515. 2014; 8:23-29.
3. Abedi Z, Hasantabar F, Khalesi MK, Babaei S. Enzymatic Activities in Common Carp; *Cyprinus carpio* Influenced by Sublethal Concentrations of Cadmium, Lead, Chromium. *World J. Fish Marine Sci.* 2013; 5(2):144-151.
4. Abou EL-Naga EH, EL-Moselhy KM, Hamed MA. Toxicity of cadmium and copper and their effect on some biochemical parameters of marine fish *Mugil seheli*. *Egyptian J. Aquat. Res.* 2005; 31(2):60-71.
5. Ahmed MS, Aslam Y, Khan WA. Absorption and bioaccumulation of water-borne inorganic mercury in the fingerlings of grass carp, *Ctenopharyngodon idella*. *The Journal of Animal and Plant Sciences.* 2011; 21(2):176-181.
6. Alinnor IJ, Obiji IA. Assessment of trace metal composition in fish samples from Nworie River Pakistan. *Pakistan Journal of Nutrition.* 2010; 9(1):81-85.
7. Almazán-Rueda P, Schrama JW, Verreth JAJ. Behavioural responses under different feeding methods and light regimes of the African catfish *Clarias gariepinus* juveniles. *Aquaculture.* 2004; 231(1-4):347-359.
8. Anees MA. Acute toxicity of four organophosphorus insecticides to freshwater teleost *Channa punctatus*. *Park. J. Zoo.* 1975; 7:135.
9. APHA (American Public Health Association). Standard Methods of Water and Wastewater. 18th ed. American Public Health Association, American Water Works Association, Water Environment Federation publication. APHA, Washington D.C, 1992.
10. Areola OO, Williams-Johnson M, Jadhav AL. Relationship between lead accumulation in blood and soft tissues of rats subchronically exposed to low levels of lead. *Toxic Subst. Mech.* 1999; 18:1-13.
11. Arunachalam S, Palanichamy S. Sublethal effects of carbaryl on surfacing behaviour and food utilization in the air breathing fish *Macropodus cupanus*. *Physiol. Behav.* 1982; 29:23-27.

12. Arunachalam SK, Jayalakshmi, Aboobucker S. Toxic and sublethal effects of carbaryl on freshwater catfish *Mystus vittatus*. *Arch. Environ. Contam. Toxicol.* 1980; 9:307-316.
13. Baskaran P, Palanichamy S, Balasubramanian MP. Effect of pesticides on protein metabolism in *Mystus vittatus*. *J. Ecobiol.* 1989; 1(2):90-97.
14. Beyersmann D, Hartwig A. Carcinogenic metal compounds: recent insight into molecular and cellular mechanisms. *Archives of Toxicology.* 2008; 82(8):493-512.
15. Buikema AL, RR Niedertehner, Cairns J. Biological monitoring part IV-Toxicity testing, *Jr. Water Res.* 1982; 16:239-262.
16. Carvalho CS, Fernandes MN. Effect of temperature on copper toxicity and haematological responses in the neotropical fish *Prochilodus scrofa* at low and high pH. *Aquaculture*, 2006; 251:109-117.
17. Cattaglin WA, Fairchild JF. Potential toxicity of pesticides measured in mid-western streams to aquatic organisms. *Water Sci Technol.* 2002; 45:95-103.
18. Chebbi SG, David M. Modulation in the protein metabolism under sublethal concentration of Quinalphos intoxication in the freshwater common carp, *Cyprinus carpio* (Linnaeus, 1758). *Int. J. Pharma. Biol. Arch.* 2011; 2(4):1183-1189.
19. Cohn J, MacPhail RC. Ethological and experimental approaches to behavior analysis, implications for ecotoxicology. *Environ. Health Perspect.* 1996; 104:299-304.
20. Cowell EB, Barker JM, Crapp GB. The biological effect of oil pollution and oil cleaning material on littoral communities including salt marshes, In: Rouvio M (ed) Marine pollution and sea life, FAO Tech. Conf. Rome. 1972; 2(3):359-364.
21. Craddock DR. Use and limitations of acute toxicity test- a review. In Malins, Dc (ed), Effect of petroleum on arctic and sub-arctic marine environment and organism, *Academic press*, New York, 1977, 1-93.
22. Das S, Kaviraj A. Cadmium accumulation in different tissues of common carp, *Cyprinus carpio* treated with activated charcoal, EDTA and single superphosphate. *Geobios.* 2000; 27:69-72.
23. Drummond RA, Russom CL. Behavioural toxicity syndromes, a promising tool for assessing toxicity mechanisms in juvenile fathead minnows, *Environ. Toxicol. Chem.* 1990; 9:37-46.
24. Dutta HM, Dalal R. The effect of endosulfan on the ovary of bluegill sunfish: a histopathological study (*Lepomis macrochirus* sp). *Int. J. Environ. Res.* 2008; 2:215-224.
25. Fergusson JE. Editor, the Heavy Elements: Chemistry, Environmental Impact and Health Effects. *Oxford: Pergamon Press.* 1990; 1990:232-244.
26. Filipovic V, Raspor B. Metallothionein and metal levels in cytosol of liver, kidney and brain in relation to growth parameters of *Mullus surmuletus* and *Liza aurata*. From the eastern Adriatic Sea. *Water Res.* 2003; 37(13):3253-3262.
27. Firat O, Cogun HY, Yüzereroglu TA, Gök G, Firat O, Kargin F, Kötemen Y. A comparative study on the effects of a pesticide (cypermethrin) and two metals (copper, lead) to serum biochemistry of *Nile tilapia*, *Oreochromis niloticus*. *Fish Physiol. Biochem.* 2011; 37(3):657-666.
28. Nussey G Van Vuren JHJ, Du Preez HH. Bioaccumulation of chromium, manganese, nickel and lead in the tissues of the moggel, *Labeo umbratus* (Cyprinidae), from Witbank Dam, Mpumalanga, *Water SA.* 2000; 26(2):269-284.
29. Gurusamy K, Ramadoss V. Impact of DDT on oxygen consumption and opercular activity of *Lepidocephalichthys thermalis*. *J. Ecotoxicol. Environ. Monit.* 2000; 10(4):239-248.
30. Karadede H, Unl EU. Concentrations of some heavy metals in water, sediment and fish species from the Atatürk Dam Lake (Euphrates), Turkey, *Chemosphere.* 2000; 41(9):1371-1376.
31. Ozyurt H, o'g'ut S, Yildirim S. *et al.*, Inhibitory effect of caffeic acid phenethyl ester on bleomycin-induced lung fibrosis in rats, *Clinica Chimica Acta.* 2004; 339, 1-(2):65-75.
32. Herger W, Jung SJ, Peter H. Acute and prolonged toxicity to aquatic organisms of new and existing chemicals and pesticides. *Chemosphere.* 1995; 31:2707-26.
33. Israeli-Weinstein D, Kimmel E. Behavioural response of carp, *Cyprinus carpio* to ammonia stress. *Aquaculture.* 1998; 165(1):81-93.
34. Das JS, Ravikanth VV, Sujatha M. Nitric oxide as a major risk factor for oxidative stress in coronary artery disease: a preliminary investigation, *Science and Culture.* 1998-2010; 76, 56:174-175.
35. Jayakumar P, Paul VI. Patterns of cadmium accumulation of the catfish *Clarias batrachus* (Linn.) exposed to sublethal concentration of cadmium chloride. *Veterinarshki Archiv.* 2006; 76:167-177.
36. Jayalakshmi S, Pugazhendy K, Tamizhazhagan V, Sakthidasan V, Jayanthi C, Sasikala P. Therapeutic efficacy of *Alovera* against the effect of cypermethrin toxicity in the freshwater *Cyprinus carpio*. *International Journal of Zoology and Applied Bioscience.* 2017; 2(6):386-391.
37. Jensen CS, Garsdal L, Baatrup E. Acetylcholinesterase inhibition and altered locomotor behaviour in the carabid beetle *Pterostichus cupreus*. A linkage between biomarkers at two levels of biological complexity. *Environ. Toxicol. Chem.* 1997; 16:1727-1732.
38. Kabata-Pendia A. 3rd, editor. Trace Elements in Soils and Plants. Boca Raton, FL: CRC Press, 2001.
39. Krebs CT, Burns KA. Long term effect of an oil spill on the salt marsh Crab *Uca pugnax* *Sci.* 1977; 197:484-487.
40. Kumar P, Prasad Y, Patra AK, Swarup D. Levels of Cadmium and Lead in Tissues of Freshwater Fish (*Clarias batrachus* L.) and Chicken in Western UP (India). *Bull. Environ. Contamin. And Toxicol.* 2007; 79:396-400.
41. Kumar P, Prasad Y, Patra AK, Ranjan R, Patra RC, Swarup D, Singh SP. Ascorbic acid, garlic extract and taurine alleviate cadmium-induced oxidative stress in freshwater catfish (*Clarias batrachus*). *The Sci. Total Environ.* 2009; 407:5024-5030.
42. Kumar P, Prasad Y, Ranjan R, Swarup D, Pattanaik AK,

- Patra RC. Accumulation Pattern of Cadmium in Tissues of Indian Catfish *Clarias batrachus*. *Animal Nutrition. And Feed Technol.* 2008; 8(1):115-119.
43. Laxi R. Cadmium contamination in common Indian food items, Himalayan J. Environ. Zool, 2005, 19-23.
 44. Little EE, Finger SE. Swimming behaviour as an indicator of sublethal toxicity in fish, *Environ. Toxicol. Chem.* 1990; 9:13-19.
 45. Ashraf MA, Maah MJ, Yusoff I. Bioaccumulation of heavy metals in fish species collected from former tin mining catchment. *International Journal of Environmental Research.* 2012; 6(1):209-218.
 46. Sugiyama M. Role of physiological antioxidants in chromium (VI)-induced cellular injury, *Free Radical Biology and Medicine.* 1992; 12(5):397-407.
 47. Malla Reddy P, Bashamohideen MD. Toxic impact of fenvalerate on protein metabolism in the branchial tissue of a fish *Cyprinus carpio*. *Curr. Sci.* 1989; 57:211-212.
 48. Meenambal M, Pugazhendy K, Vasantharaja C, Venkatesan S. Ameliorative property of *Delonix elata* supplementary feed against cypermethrin induced serum biochemical changes in fresh water fish *Cyprinus carpio* (Linn). *Journal of Pharmacy Research.* 2012; 5(5):2489-2492.
 49. Morel FMM, Kraepiel AML, Amyot M. The chemical cycle and bioaccumulation of mercury. *Annual Rev. Ecol. Systematics.* 1998; 29:543-566.
 50. Murthy AS, Sub lethal effect of pesticides on fish. *Toxicity of pesticides to fish.* 1987; 2:55-100.
 51. Nagaraju Bantu, Rathnamma vakita. Effect of Dimethoate on mortality and Biochemical changes of Freshwater fish *Labeo rohita* (Hamilton). *J. Biol. Today's World.* 2013; 2(6):108-117.
 52. NAS/NAE (National Academy of sciences/ National Academy of Engineering. Water quality criteria. EPA-R3-033, 1971. Washington. 1972; 24:1701.
 53. Nguyen VC, Nguyen TP, Mark B. Brain cholinesterase response in the snakehead fish (*Channa striata*) after field exposure to diazinon. *Ecotoxicol. Env. Safe.* 2008; 71:314-318.
 54. Nisar Shaikh, Yeragi SG. Effect of Rogor 30E (Organophosphate) on muscle protein in the fresh water fish *Lepidocephalecthes thermalis*. *J. Ecotoxicol. Environ. Morit.* 2004; 14(3):233-235.
 55. Erdo O'grul, Ayfer A. Determination of cadmium and copper in fish samples from Sir and Menzelet Dam Lake Kahramanmaras., Turkey, *Environmental Monitoring and Assessment.* 2006; 117(1-3):281-290.
 56. Lushchak OI, Kubrak MZ, Nykorak KB, Storey VI. Lushchak, The effect of potassium dichromate on free radical processes in goldfish: possible protective role of glutathione, *Aquatic Toxicology.* 2008; 87(2):108-114.
 57. Olsson PE, Kling P, Hogstrand C. Mechanisms of heavy metal accumulation and toxicity in fish. *Metal Metabolism in Aquatic Environments,* 1998, 321-350.
 58. Olsson PE. Disorders associated with heavy metal pollution. In: *Fish Diseases and Disorders Volume 2 (Non-infectious Disorders)*. (Eds. Leatherland, J.E. and Woo, P.T.K.), *CABI International.* 1998; UK:105-131.
 59. Padmapriya K, Pugazhendy K, Tamizhazhagan V, Sakthidasan V, Jayanthi C. Impact of simazine and chelate properties of *Solanum xanthopium* is the freshwater fish *cirrhinus mrigala* Hematological studies for the period of 120 hours. *International Journal of Pharmacy and Biological Sciences.* 2017; 7(3):185-189.
 60. Pichaimani N, Pugazhendy K, Tamizhazhagan V, Sakthidasan V, Jayanthi C, Sasikala P. Antioxidant enzyme activity effect of *Solanum virginianum* against lead Acetate toxicity of the fresh water fish *Cyprinus carpio*. *International Journal of Current Advanced Research.* 2017; (6)12:8031-8037.
 61. Pugazhendy K, Susiladevi M, Jayanthi C, Jayachandaran K, Meenkshi V. Impact of Industrial Pollutants on the Gill of Mullet Fish, *Mugil Cephalus* in the Uppanar Estuary, (Sipcot) Cuddalore on the South East Coast of India. 2008; 27(2):231-236.
 62. Pugazhendy K, Susiladevi M, Jayanthi C, Jayachandaran K, Meenkshi V. Impact of industrial pollutants on the gill of mullet fish, *Mugil Cephalus* in the Uppanar Estuary, (Sipcot) Cuddalore on the South East Coast of India, *Poll. Res.* 2008; 27(2):231-236.
 63. Sultana R, Rao DP. Bioaccumulation patterns of zinc, copper, lead, and cadmium in grey mullet, *Mugil cephalus* (L.), from Harbour waters of Visakhapatnam, India, *Bulletin of Environmental Contamination and Toxicology.* 1998; 60(6):949-955.
 64. Roy PK, Datta Munshi JS. Oxygen consumption and ventilation rate of fresh water major carp, *Cirrhinus mrigala* (Ham). In fresh and Malathion treated waters, *J. Environ. Physiol.* 1988; 9(1):05-13.
 65. Vutukuru SS. Chromium induced alterations in some biochemical profiles of the Indian major carp, *Labeo rohita* (Hamilton), *Bulletin of Environmental Contamination and Toxicology.* 2003; 70(1):118-123.
 66. Matsumoto ST, Marin-Morales MA. Mutagenic potential evaluation of the water of a river that receives tannery effluent using the *Allium cepa* test system, *Cytologia.* 2004; 69(4):399-408.
 67. Sapna Shrivastava, Sudha Singh, Keerty Shrivastava. Effect of carbaryl on glucose content in the brain of *Heteropneustes fossilis*. *J. Ecotoxicol. Environ. Monit.* 2002; 12(3):205-208.
 68. Scott GR, Sloman KA. The effects of environmental pollutants on complex fish behaviour: integrating behavioural and physiological indicators of toxicity. *Aqua. Toxicol.* 2004; 68(4):369-392.
 69. Singh DN, Tyagi RK, Panwar RS. Toxicity of some organobiocides to a fish *Cyprinus carpio* var communis. *J. Environ. Physiol.* 1981; 2(3):41-46.
 70. Sprague JB. Measurement of pollutant toxicity to fish-I. Bioassay methods for acute toxicity *Water Res.* 1969; 3:793-821.
 71. Brien J, Xu, Patierno SR. Effects of glutathione on chromium-induced DNA. Crosslinking and DNA polymerase arrest, *Molecular and Cellular Biochemistry.* 2001; 222, 1-2:173-182.
 72. Tabinda AB, Bashir S, Yasar A, Hussain M. Metals concentrations in the riverine water, sediments and fishes from river Ravi at ballokiheadworks. *The journal of animal & plant sciences.* 2013; 23(1):76-84.

73. Tadehl H, Häder DP. Automated biomonitoring using real time movement analysis of *Euglena gracilis*. *Ecotoxicol. Environ. Saf.* 2001; 48:161-169.
74. Tamizhazhagan V, Pugazhendy K, Sakthidasan V, Jayanthi C, Barbara Sawicka, Agevi Humphrey, Vasanth pandiyan C, Kasinathan M, Ramarajan K, Baranitharan M. Study of toxic effect of monocrotophos 36% E.C on the biochemical changes in fresh water Fish *Catla catla* (Hamilton, 1882). *International Journal of Chemical & Pharmaceutical Analysis.* 2017; 4(3):1-9.
75. Tamizhazhagan V, Pugazhendy K, Sakthidasan V, Jayanthi C. The toxicity effect of monocrotophos 36 % E.C on the Histological changes in gill of *Labeo rohita*. *International journal of innovative research in multidisciplinary field.* 2016; 2(11):435-439.
76. Tamizhazhagan V, Pugazhendy K, Sakthidasan V, Jayanthi C, Barbara Sawicka, Shuuduv Gerlee, Ramarajan K, Manikandan P. The toxicity effect of pesticide Monocrotophos 36% E.C on the enzyme asctivity changes in liver and muscles of *Labeo rohita* (Hamilton, 1882). *International Journal of Pharma Sciences and Research.* 2017; 8(5):60-67.
77. Tamizhazhagan V. The toxicity effect of monocrotophos 36 %E.C on the Haematology, *Labeo rohita* (Hamilton, 1882). *Int J Curr Pharm Res.* 2015; 7(4):92-95.
78. Tamizhazhagan V, Pugazhendy K. Physico-Chemical parameters from the Manappadaiyur and Swamimalai freshwater Ponds. *Indo American journal of Pharmaceutical Science.* 2016; 3(5):444-449.
79. Tamizhazhagan V, Pugazhendy K. The toxicity effect of monocrotophos 36% E.C on the Biochemical changes *Labeo rohita* (Hamilton, 1882). *International Journal for Scientific Research and Development.* 2016; 3(11):802-808.
80. Ullah S, Ullah N, Rahman K, Khan TM, Jadoon MA, Ahmad T. Study on Physicochemical Characterization of Konhaye Stream District Dir Lower, Khyber Pakhtunkhwa Pakistan. *World J. Fish and Mar. Sci.* 2014; 6(5):461-470.
81. Usha R, Pugazhendy K, Tamizhazhagan V, Sakthidasan V, Jayanthi C. Potential efficacy of *Tribulus terretri* against toxic impact of chlorpyrifos on hematological alteration in the fresh water fish *Oreochrommis mossambicus*. *International Journal of Zoology and Applied Biosciences.* 2017; 2(5):232-240.
82. Patil VK, David M. Oxidative stress in freshwater fish, *Labeo rohita* as a biomarker of Malathion exposure, *Environmental Monitoring and Assessment.* 2013; 185:10191-10199.
83. Velma V, Tchounwou PB. Chromium-induced biochemical, genotoxic and histopathologic effects in liver and kidney of goldfish, *Carassius auratus*, Mutation Research: *Genetic Toxicology and Environmental Mutagenesis.* 2010; 698:1-2, 43-51.
84. Verkleji JAS. The effects of heavy metals stress on higher plants and their use as biomonitors In *Plant as Bioindicators: Indicators of Heavy Metals in the Terrestrial Environment.* Markert, B., editor. New York: VCH, 1993, 415-424.
85. Viran R, Erkoç FU, Polat H, Kocak O. Investigation of acute toxicity of deltamethrin on guppies *Poecilia reticulata*. *Ecotoxicol. Environ. Saf.*, 55, 82-85. doi: 10.1016/S0147-6513(02)00096-9, 2003.
86. Visvanathan P, Maruthanayagam C, Govindaraju M. Effect of Malathion and endosulfan on biochemical changes in *Channa punctatus*. *J. Ecotoxicol. Environ. Monit.* 2009; 19(3):251-257.
87. Wang S, Shi X. Molecular mechanisms of metal toxicity and carcinogenesis *Molecular and Cellular Biochemistry.* 2001; 222:3-9.
88. Xie P, Zhuge Y, Dai M. Impacts of eutrophication on biodiversity of plankton community. *Acta Hydrobiol. Sinica.* 20(suppl.), 1996, 30-37.
89. Yousaf S, Zada A, Owais M. Physico-chemical characteristics of potable water of different sources in District Nowshera: A case study after flood – 2010. *J. Himalayan Earth Sci.* 2013; 46(1):83-87.
90. Yousafzai AM, Khan AR, Shakoori AR. Heavy Metal Pollution in River Kabul Affecting the Inhabitant Fish Population. *Pakistan Journal of Zoology.* 2008; 40(5):331-339.
91. Herger R, Willmott P, Schlepütz C, Björck M, Pauli S, Martoccia D, Yacoby Y. Structure determination of monolayer-by-monolayer grown La 1– x Sr x MnO 3 thin films and the onset of magnetoresistance. *Physical Review B.* 2008; 77(8):085401.
92. Pugazhendy K, Revathi A, Prabakaran S, Murugan K, Hwang JS. Convalesce consequence of *Pisonia alba* and *Cardiospermum halicacabum* aligned with the atrazine inebriated on antioxidant enzymes and histological changes in liver tissue of *Rattus norvegicus*. *International Journal of Advanced Life Science.* 2008; 8(1):10-19.
93. Senthilmurugan S, Sattanathan G, Vijayan PPK, Tamizhazhagan V. Evaluation of different concentration of vermiwash on seed germination and biochemical response in *Abelmoschus esculentus* (L.). *Evaluation,* 2018, 3(1).
94. Tamizhazhagan V. Study of toxic effect of monocrotophos 36% EC on the biochemical changes in fresh water fish *Catla catla* (Hamilton, 1882). *International Journal of Chemical and Pharmaceutical Analysis,* 2017, 4(3).
95. Tamizhazhagan V, Pugazhendy K. The toxicity effect of Monocrotophos 36% Ec on the Hematology, *Labeo rohita* (Hamilton, 1882). *Int J Curr Pharm Res.* 2015; 4:92-95.
96. Tamizhazhagan V, Pugazhendy K. Physico-chemical parameters from the manappadaiyur and swamimalai fresh water ponds. *Indo American Journal of Pharmaceutical Sciences.* 2016a; 3(5):444-449.
97. Tamizhazhagan V, Pugazhendy K. The toxicity effect of Monocrotophos 36% EC on the Biochemical changes *Labeo rohita* (Hamilton, 1882). *International Journal for Scientific Research & Development.* 2016b; 3(11):802-808.
98. Vijayan P, Senthilmurugan S, Pugazhendy K, Tamizhazhagan V. Analysis of physicochemical parameters water samples from Cauvery River in Thanjavur district, Tamil Nadu. *Analysis,* 2018, 3(1).