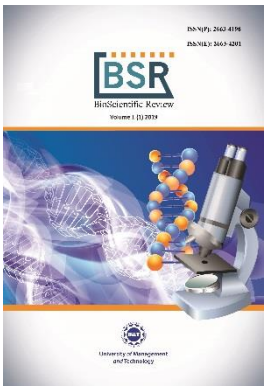

BioScientific Review (BSR)

Volume No.1, Issue No. 3, 2019
ISSN(P): 2663-4198 ISSN(E): 2663-4201
Journal DOI: https://doi.org/10.32350/BSR
Issue DOI: https://doi.org/10.32350/BSR.0103
Homepage: https://ssc.umt.edu.pk/Biosci/Home.aspx

Journal QR Code:

Article: **Hazardous Effects of Arsenic Contaminated Water on the Biological Characteristics of Fishes: A Review**

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Article DOI: https://doi.org/10.32350/BSR.0103.01

Article QR Code:

Maimoona Kanwal

To cite this article: Kanwal M, Hussain M, Younus W. Hazardous effects pf Arsenic contaminated water on the biological characteristics of fishes: A review. *BioSci Rev*. 2019;1(3):01–08.
Crossref

A publication of the
Department of Life Sciences, School of Science
University of Management and Technology, Lahore, Pakistan

Hazardous Effects of Arsenic Contaminated Water on the Biological Characteristics of Fishes: A Review

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Abstract

The aim of the current review is to deliberate on arsenic chemistry, its existence in aquatic ecosystem and its effects on the biological systems of fishes which are regarded as potential indicators for any change in water quality. Water is a major storehouse of arsenic which is present in the form of arsenate and arsenite. Anthropogenic activities including unlimited application of arsenic pesticides, industrial activities and mining operations have increased the universal incidence of soluble arsenic above tolerable levels of 0.010 mg/L. Variations in fish behaviour, growth rate, haematological and biological parameters and organ systems have been observed in arsenic contaminated water. Data regarding these parameters indicate that the fish shows aggressive behaviour and its weight increases due to a high arsenic uptake. The production rate of biochemical compounds like carbohydrates, proteins and lipids is reduced due to arsenic bonding with their precursors. Among organ systems, skin is a highly affected organ, while muscles are the least affected due to high arsenic concentration. Low concentration of arsenic results in bioaccumulation, conspicuously in liver and kidney, upon incessant exposure to freshwater fish. This bioaccumulation turns into biomagnification and becomes the cause of lethal diseases in human beings, such as hyperglycaemia, diminution of enzymatic activities and immune system abnormalities. Keeping in view all of these above mentioned facts, it is imperative to take action against excessive arsenic usage and to develop its eco-friendly management ways.

Keywords: arsenic, fish biology, haematological -changes, heavy metal toxicity, water contmination

1. Introduction

Arsenic (As) is a mobile, toxic, and carcinogenic element that is widely dispersed in aquatic environment, mostly in the form of sulphide and oxide complexes. It has three modes of existence, that is, arsine gas, organic and inorganic existence which are normal, moderately and highly toxic, respectively [1]. Due to its toxicity, it poses serious threats to the environment [2]. Anthropogenic activities including industrial processes, preservation of timber and burning of fossil fuels have led to its increased concentration in our environment that causes haematological and biochemical damage to organisms and has also resulted in worldwide health issues, such as food poisoning. Arsenic contamination has badly affected the aquatic fauna with fishes being the highly disturbed organisms in this ecosystem. So, it is being used as a model while studying environmental pollution caused by arsenic [3] because they are greatly affected by the

presence of arsenic in water. It results in bioaccumulation and biomagnification which act as risks for higher trophic levels [4]. This review mainly emphasizes arsenic's chemical nature, occurrence in the environment, contamination, estimation of the adverse effects of changes in physiology, biochemistry, haematology, behaviour and metabolism of fishes in arsenic contaminated water.

2. Chemical Forms of Arsenic

Arsenic is a brittle metal belonging to VA group with the atomic weight of 74.92 and melting and sublimation points at 817 ºC and 613 ºC, respectively. It has three allotropic forms, yellow, black, grey. It belongs to VA group with four oxidation states, that is, –3, 0, +3, and +5. It has two trivalent forms, arsenide and arsenic trichloride. Its pentavalent forms are arsenic pentoxide, arsenic acid and arsenates [5]. Its chemical forms are described in Table 1.

It is known that toxicity caused by arsenic is due to the creation of imbalances between pro-oxidant and antioxidant homeostasis which leads to oxidative stress.

3. Effects on Fishes

Fishes are highly developed aquatic organisms and any change in water qualities can have adverse effects on

them, including variations in haematology, biochemistry and various organ systems. Potential indicators used to detect toxicity in fishes are alanine aminotransferase and aspartate aminotransferase enzymes. The effects of arsenic can be determined by arsenic exposure to these enzymes and it was concluded that arsenic exposure for 96 hours to Indian Major Carp caused increased activity of these enzymes that resulted in hepatic damage [6].

Table 1. Various Chemical Forms of Arsenic Compounds

Arsenic	Solid, insoluble in water and highly toxic
Arsenic acid	Solid, freely soluble in water and toxic
Arsenic trioxide	Solid, slightly soluble in water and highly toxic
Arsenic pentaoxide	Amorphous solid, freely soluble, moderately toxic
Sodium Arsenate	Solid, very soluble
Arsine gas	Solid, freely soluble
Dimethylar-sonate	Solid, moderately toxic
Arsenobeta-ine	Solid, non-toxic

3.1. Behavioural and Growth Changes in Fishes

When a change occurs in the surroundings of fishes, they respond to it by changing their behaviour as in the case of arsenic contamination. An experiment was conducted on the invasive mosquito fish in laboratory by providing a natural environment in which certain algae were also present to check their effect on low arsenic level [7]. As the arsenic level increased, it lead to a significant increase in the aggression level of fishes and decreased operculum movement. Arsenic accumulation in the body of fish increases its weight and algae acts as nature defence mechanism to control weight gain [7]. Another laboratory experiment was conducted on rainbow trout and feathered minnows upon exposure to diet borne and water borne arsenic for 28 hours. Trout growth is affected when >10 µg As/L is given while 16 mg As/L quantity of arsenic leads to growth reduction and high mortality. Mortality rate in feathered

minnows is high even with little concentration of arsenic; however, trout is more sensitive than minnows in this regard as far as growth rate is concerned. When growth effects are based on accumulation in the fish, waterborne and diet borne exposures show similar dosimetry and are roughly additive [8].

3.2. Effects on Organ Systems of Fishes

Fishes are ideal organisms to work with in toxicogenomic studies due to the strong power of fish models to establish the biomarkers of exposure. Arsenic affects fishes in the same way as it affects human, that's why fishes are widely taken as the study model. Various organ systems of fishes such as liver, kidney, brain, skin, lungs and muscles are affected by arsenic exposure (Table 2).

3.2.1. Effects on liver. Liver plays a major role in the uptake, accumulation, biotransformation and excretion of arsenic and liver damage is greater at high concentrations of arsenic as was observed in *Channa punctuata*. Its maximum mortality rate was observed at 100ppm, within 18-20h of exposure [9].

A toxic form of arsenic, that is, sodium arsenate leads to the fragmentation of the chromosomal DNA of fish liver. In case of accumulated in a large concentration in the liver and but when arsenic exposure is long, it causes complete degradation of the liver. Upon exposure to low dose sodium sublethal concentration of arsenic in Indian catfish leads to the induction of significant changes in liver cells. It causes reduction in total protein contents in liver cells [11]. Many other degenerative changes, such as apoptosis and pyknosis in hepatocytes of fishes are observed when they are exposed to different sublethal arsenic concentrations [12].

Table 2. Effect of Arsenic on Organs of Various Fishes

Fishes	Affected organs
Clarias batrachus	Liver, gills, blood, skin, brain
Danio rerio	Muscles, liver, gills, bone, gut, fins
Clarias gariepinus	Gills, blood, muscle, skin, brain
Common carp	Kidney, liver, fins, scales
Danio rerio	Liver, gills, muscle, heart
Labeo rohita	Muscles, Intestine
Tilapia zilli	Gills, Intestine, Liver

3.2.2. Effects on skin. Skin is directly connected with environment. So, any hazardous fluctuations in the habitat will lead to perilous variations of skin. Upon exposure to arsenic, large amount of mucous is formed on the skin of the fish which is basically composed of glycoprotein and sulphated mucin which have the ability to bind with arsenic. So, it temporarily prevents the skin from an arsenic attack. Long term arsenic exposure gives rise to skin complications, as in *Clarias batrachus* arsenic contaminated water, which causes wear and tear of skin and hyperplasia of mucous cells [13].

3.2.3. Effects on kidney. Kidney is a major osmoregulatory organ in fishes and it is involved in arsenic removal. However, renal histopathology is greatly affected by acute arsenic exposure as observed in lake white fish and lake trout [14]. It was observed that upon arsenic exposure, a change in the volume of kidney occurs as glomerulus shrinks and Bowman's capsule increases in volume that shows an increased rate of filtration and urine concentration [15].

3.2.4. Effects on brain. Brain is the control house of all organs. So, it is at a higher risk of damage with arsenic

pollution. It was shown in *Labeo rohita* that brain intoxicated with arsenic leads to reduced production of proteins because arsenic easily reacts with free amino acids. Thus, they are no longer available for protein production [16]. Brain endonucleotidase activities are also disturbed by chronic exposure to arsenic [17].

3.2.5. Effects on muscles: Fishes usually comprise up to 80% muscle tissues which play a major role in swimming activities. They are somewhat resistant to arsenic contents and least affected due to the absence of any direct connection between them. However, as the age of fish increases, the accumulation of arsenic in muscles also increases. While arsenic exposure during the early stages of fish growth may lead to muscle dysfunction. Several types of malfunctioning including necrosis, atrophy and molecular degeneration are detected when *H. fossilis* is exposed to between 7 and 20 mg/L of arsenic [18].

3.3. Biochemical Changes in Fishes

Biochemical parameters are affected by change at molecular level upon exposure to arsenic contaminated water. Among these parameters, blood glucose level is a majorly affected parameter [11].

3.3.1. Blood carbohydrate level. is highly suppressed by arsenic in water. Arsenic induced hyperglycaemic effects in three major Indian carps at the level of sublethal dosage. It resulted in similar hyperglycaemic effects on *Tilapia zillii* and *Mugil capito*. It was observed that hyperglycaemic effects were due to extensive glycogenolysis [13]. Another cause found was that the beta cells of pancreas altered their insulin secreting capacity due to mutation in gene expression of insulin related genes that resulted in less insulin production.

3.3.2. Proteins. are also affected by arsenic and its metabolites because arsenic reacts with phosphates and the thiol group of proteins leading to its impairment. Arsenic metabolism releases free radicals that also cause damage to protein structure. Inorganic forms of arsenic such as arsenite and arsenate bind with sulfhydryl and phosphate groups, respectively. Usually, upon exposure to arsenite, heat shock proteins get activated and their expression patterns depend on the specific dose and tissue. These proteins are involved in cell protection by ensuring cell survival [19]. *Labeo rohita* was exposed to sublethal concentrations of arsenic for 28 days and a significant reduction in protein contents was observed [20]. It was observed that fish liver proteome is altered in Zebra fish on exposure to 50 g/L sodium arsenide for seven days [21]. These findings illustrate that arsenic contaminated water results in transmuted protein expression along with the activation of heat shock proteins.

3.3.3. Lipids. are also an important physiological component and after arsenic exposure lipolysis is enhanced. It was shown that 1.0 mg As/L exposure of arsenic to rainbow trout resulted in decreased dry weight of fish although the wet weight remained the same [22]; however, an increased concentration of arsenic leads to a decrease in wet weight also. This decreased weight is due to kidney damage on arsenic exposure [23]. For lipid contents, the duration and route of arsenic exposure also matters. In this context, a study was conducted on *Anabas testudineus* [10]. After the fish was exposed to arsenic at the rate of 1.5 mg/L level, significant changes in lipid level were observed. It was observed regarding *Fundulus heteroclitus* that arsenic exposure may reduce cholesterol homeostasis, which can have adverse effects on fishes. Thus, arsenic

contaminated water may cause changes in carbohydrates, proteins and lipids levels in fishes [24].

3.4. Haematological Changes in Fishes

Changes in haematological parameters are also observed in fishes living in arsenic contaminated water. They act as indicators for environmental disturbances. It helps in the diagnoses of the functional status of fishes [25]. Haematological parameters are affected by oxidative stress in fish liver. The duration of arsenic exposure includes acute and chronic exposure. Acute and chronic exposure cause reduction in the number of erythrocytes and leukocytes, respectively. Haematological parameters were determined by taking *Catla catla* as model organism. 43.78 mg/L arsenic was provided to the fish for 96 hours. It declined the normal values of haemoglobin, plasma, RBC, and WBC count, while the mean cell volume, mean cell haemoglobin and mean cell haemoglobin concentration were increased [24]. A decreased level of haemoglobin was observed in *C. batrachus* exposed to waterborne arsenic [26].

4. Conclusion

Arsenic is a heavy metal and its concentration is increasing in the aquatic environment day by day due to both natural and anthropogenic activities. Fishes are taken as an indicator of arsenic contamination. Many research works have unveiled that arsenic contamination has hazardous effect on liver and kidney. It disturbs the normal body functioning that results in onset of diseases. Understanding the noxious effects of arsenic in the aquatic ecosystem is helpful to reduce its effects on fishes and other organisms, such as human beings who eat fish. Consistent observations of arsenic levels assist us to monitor health hazards associated with arsenic contamination in fishes. These fishes do not provide a complete insight into the overall conditions of the ecosystem; still, it is helpful to reveal the potential effects of arsenic contamination on food chain.

5. Recommendations

Arsenic contamination is hazardous for fish health and its major sources are natural and anthropogenic activities, so it is recommended here to make laws against the release of arsenic wastes. People should be made aware about the harmful effects of arsenic through seminars and conferences and they should be charged in case of rules' violation. It is also recommended that biological control as well as phytoremediation should be applied to treat contaminated water. A lot of research should be conducted on the cleaning of water through phytoremediation due to the absence of any side effects.

References

[1] Duker AA, Carranza E, Hale M. Arsenic geochemistry and health. *Environ Int*. 2005 Jul 1;31(5):631–41.

[2] Bundschuh J, Litter MI, Parvez F, Román-Ross G, Nicolli HB, Jean JS, et al. One century of arsenic exposure in Latin America: a review of history and occurrence from 14 countries. *Sci Total Environ*. 2012 Jul 1; 429:2–35.

[3] Gernhöfer M, Pawert M, Schramm M, Müller E, Triebskorn R. Ultrastructural biomarkers as tools to characterize the health status of fish in contaminated streams. *J Aquat Ecosys Stress Recovery*. 2001 Sep 1;8(3-4):241–60.

[4] Xu H, Lam SH, Shen Y, Gong Z. Genome-wide identification of molecular pathways and biomarkers in

response to arsenic exposure in zebrafish liver. *PloS One*. 2013 Jul 29;8(7):e68737.

[5] Gaim K, Gebru G, Abba S. The effect of arsenic on liver tissue of experimental animals (fishes and mice)—a review article. *Int J Sci Res Publ*. 2015 May;5(5):1–9.

[6] Vutukuru S, Prabhath N, Raghavender M, Yerramilli A. Effect of arsenic and chromium on the serum amino-transferases activity in Indian major carp, *Labeo rohita*. *Int J Environ Res Public Health*. 2007 Sep;4(3):224–7.

[7] Magellan K, Barral-Fraga L, Rovira M, Srean P, Urrea G, García-Berthou E, et al. Behavioural and physical effects of arsenic exposure in fish are aggravated by aquatic algae. *Aquat Toxicol*. 2014 Nov 1; 156:116–124.

[8] Erickson RJ, Mount DR, Highland TL, Hockett JR, Leonard EN, Mattson VR, et al. Effects of copper, cadmium, lead, and arsenic in a live diet on juvenile fish growth. *Can J Fish Aquat Sci*. 2010 Oct 28;67(11):1816–26.

[9] Das S, Unni B, Bhattacharjee M, Wann SB, Rao PG. Toxicological effects of arsenic exposure in a freshwater teleost fish, *Channa punctatus*. *Afr J Biotechnol*. 2012;11(19):4447–54.

[10] Carlson P, Smalley DM, Van Beneden RJ. Proteomic analysis of arsenic-exposed zebrafish (Danio rerio) identifies altered expression in proteins involved in fibrosis and lipid uptake in a gender-specific manner. *Toxicol Sci*. 2013 Apr 30;134(1):83–91.

[11] Datta S, Ghosh D, Saha DR, Bhattacharaya S, Mazumder S. Chronic exposure to low concentration of arsenic is immunotoxic to fish: role of head kidney macrophages as biomarkers of arsenic toxicity to *Clarias batrachus*. *Aquat Toxicol*. 2009 Apr 9;92(2):86–94.

[12] Ahmed MK, Habibullah-Al-Mamun M, Hossain MA, Arif M, Parvin E, Akter MS, et al. Assessing the genotoxic potentials of arsenic in tilapia (*Oreochromis mossambicus*) using alkaline comet assay and micronucleus test. *Chemosphere*. 2011 Jun 1;84(1):143–9.

[13] Kumari B, Kumar V, Sinha AK, Ahsan J, Ghosh AK, Wang H, et al. Toxicology of arsenic in fish and aquatic systems. *Environ Chem Lett*. 2013 Mar 1;15(1):43–64.

[14] Pedlar RM, Ptashynski MD, Evans R, Klaverkamp JF. Toxicological effects of dietary arsenic exposure in lake whitefish (*Coregonus clupeaformis*). *Aquat Toxicol*. 2002 May 1;57(3):167–89.

[15] Allen T, Singhal R, Rana SV. Resistance to oxidative stress in a freshwater fish *Channa punctatus* after exposure to inorganic arsenic. *Biol Trace Elem Res*. 2004 Apr 1;98(1):63–72.

[16] Baldissarelli LA, Capiotti KM, Bogo MR, Ghisleni G, Bonan CD. Arsenic alters behavioral parameters and brain ectonucleotidases activities in zebrafish (*Danio rerio*). *Comp Biochem Physiol Part C: Toxicol Pharmacol*. 2012 May 1;155(4):566–72.

[17] Palaniappan PL, Vijayasundaram V. The bioaccumulation of arsenic and the efficacy of Meso-2, 3-di-mercaptosuccinic acid in the selected organ tissues of *Labeo rohita* fingerlings using inductively coupled plasma-optical emission spectrome-

try. *World Appl Sci J*. 2009; 6:1247–54.

[18] D'Amico AR, Gibson AW, Bain LJ. Embryonic arsenic exposure reduces the number of muscle fibers in killifish (*Fundulus heteroclitus*). *Aquat Toxicol*. 2014 Jan 1; 146:196–204.

[19] Agarwal S, Roy S, Ray A, Mazumder S, Bhattacharya S. Arsenic trioxide and lead acetate induce apoptosis in adult rat hepatic stem cells. *Cell Biol Toxicol*. 2009 Aug 1;25(4):403

[20] Pazhanisamy K, Indra N. Bioaccumulation of arsenic in the freshwater fish *Labeo Rohita* (HAM.). *Bioscan*. 2007;2(1):67–69.

[21] Bambino K, Zhang C, Austin C, Amarasiriwardena C, Arora M, Chu J, et al. Inorganic arsenic causes fatty liver and interacts with ethanol to cause alcoholic liver disease in zebrafish. *Dis Models Mech*. 2018;11(2):1–13.

[22] Cockell KA, Hilton JW. Preliminary investigations on the comparative chronic toxicity of four dietary arsenicals to juvenile rainbow trout (*Salmo gairdneri* R.). *Aquat Toxicol*. 1988 Jan 1;12(1):73–82.

[23] Gonzalez HO, Hu J, Gaworecki KM, Roling JA, Baldwin WS, Gardea-Torresdey JL, et al. Dose-responsive gene expression changes in juvenile and adult mummichogs (*Fundulus heteroclitus*) after arsenic exposure. *Mar Environ Res*. 2010 Aug 1;70(2):133–41.

[24] Adhikari S, Sarkar B, Chatterjee A, Mahapatra CT, Ayyappan S. Effects of cypermethrin and carbofuran on certain hematological parameters and prediction of their recovery in a freshwater teleost, *Labeo rohita* (Hamilton). *Ecotoxicol Environ Safety*. 2004 Jun 1;58(2):220–6.

[25] Kavitha C, Malarvizhi A, Kumaran SS, Ramesh M. Toxicological effects of arsenate exposure on hematological, biochemical and liver transaminases activity in an Indian major carp, Catla catla. *Food Chem Toxicol*. 2010 Oct;48(10):2848–54.

[26] Tripathi S, Sahu DB, Kumar R, Kumar A. Effect of acute exposure of sodium arsenite (Na3 Aso3) on some haematological parameters of *Clarias batrachus* (common Indian cat fish) in vivo. *Indian J Environ Health*. 2003 Jul;45(3):183–8.