Journal of Global Biosciences
ISSN 2320-1355
Volume 4, Number 5, 2015, pp. 2369-2374
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Review Paper

A REVIEW ON ARSENIC CONTAMINATION IN FRESH WATER FISHES OF WEST BENGAL

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Abstract

The paper reviews the contamination of arsenic (As) in the freshwater fishes. Arsenic (As) distribution and toxicology in the environment is a serious issue, with millions of individuals worldwide being affected by arsenic toxicity. Sources of As contamination are both natural and anthropogenic and the scale of contamination ranges from local to regional. The world average sediment arsenic content is usually less than 10 mg kg^{-1} and for river sediments the baseline level is 5 mg $kg^{-1.}$ Sources of As contamination are both natural and anthropogenic and the scale of contamination ranges from local to regional. There are many areas of research that are being actively pursued to address the As contamination problem.Inorganic arsenic has generally been thought to be more toxic and otherwise hazardous to animals than organic arsenic. As concentrations in the freshwater ecosystems is less than 10 µg l^{-1} and often less than 1 µg l^{-1} but for contaminated water bodies the toxicant has been found even up to thousands of microgram per liter. Thus, fish are the most vulnerable to the As toxicity.

Key words: Arsenic, Source, Freshwater, Sediment, Fish.

INTRODUCTION

The chemical symbol for arsenic is (As). Arsenic occurs in many minerals, usually in conjunction with sulfur and metals, and also as a pure elemental crystal (1). In the environment arsenic can be found as inorganic and organic compounds, in several valence states, i.e. -3, -1, 0, +3, and +5. In natural water arsenic occurs mainly in inorganic forms as trivalent arsenite [As(III)] [As(V)]. In addition, lakes arsenic can undergo microbial methylation and both As(III) and As(V) can coexist with monomethilarsonic acid (MMA) and di-methilarsinic acid (DMA) (2). There are five arsenic affected states in India (Uttar Pradesh, Bihar, Jharkhand, West Bengal, Asam).

It has been shown that fish contain arsenic both in the form of lipid soluble and water soluble arseno organic compounds (3). Acute exposures can result in immediate death because of As-induced increases in mucus production, causing suffocation, or direct detrimental effects on the gill epithelium. Chronic exposures can result in the accumulation of the metalloid to toxic levels; the detoxification role of the liver places the liver at considerable risk. However, if arsenic occurs in compounds which are essential to fish and other aquatic organisms, the possibility that they themselves are able to synthesise these compounds have to be considered (4).

SOURCE OF ARSENIC:

The source of arsenic in the environment includes natural and anthropogenic (5).

1.Natural source of arsenic:-
Arsenic is a natural constituent of the continental crust with an average content of 2 –3g/t. There are several factor like earth crusts, soil, sediments, water, air and living organisms, which are source of arsenic (5).

a)Earth crusts:
Arsenic is a rare crystal element comprising about five hundred–thousandths of 1% (0.00005%) of the earth's crust (6). The average concentration of arsenic in igneous and sedimentary rocks is 2 mg kg^{-1} and in most rocks it ranges from 0.5 to 2.5 mg kg^{-1} (7). Arsenic might be co-precipitated with iron hydroxides and sulfides in sedimentary rocks. The arsenic content rich in iron deposits, sedimentary iron ores and manganese nodules (7).

b)Soil:
Most arsenic exists in soil in the environment. The levels of arsenic in the soils of various countries range from 0.1 to 40 mg kg^{-1} (mean 6 mg kg^{-1}) (8). Uncontaminated soils usually contain 1–40 mg kg^{-1} of arsenic. The lowest concentrations of arsenic in sandy soils and larger concentrations are found in alluvial and organic soils (7) The contents of arsenic in the soils of various countries are shown in Table:1

Table 1- As concentration in various type of soil

Soil	As concentration average and/or range (mg kg^{-1})	Reference
Various	7.2 (0.1–55	Boyle et al.,1973
Peaty and bog soils	13(2-26)	
Acid Sulphate Soil	6-41	
Soils near sulphide deposits	2-126	

c)Sediment:
Sediments in aquatic systems mostly present higher arsenic .The natural level of arsenic in sediments is usually below 10 mg kg^{-1} (9). The concentration of arsenic in river sediment sand 5 mg kg^{-1} (10) .As concentrations in sediments from the river Ganges averaging 2.0 (range: 1.2 – 2.6) mg kg^{-1}, from the Brahmaputra river averaging 2.8 (range 1.4 – 5.9) mg kg^{-1} and from the Meghna river averaging 3.5 (range 1.3 – 5.6) mg kg^{-1} (11).

d)Rocks:
Arsenic concentrations in igneous rocks are generally similar to the earth crust. An average value of 1.5 mg kg^{-1} for all rock types. Silica content are slightly higher than this value but generally less than 5 mg kg^{-1}. Volcanic glasses are slightly higher with an average of around 5.9 mg kg^{-1}(12).

e)Atmosphere:
The concentrations of arsenic in the atmosphere are usually low. The concentration of arsenic in atmosphere are increased by inputs from smelting ,other industrial operations, fossil-fuel combustion and volcanic activity. The concentrations of arsenic is around 10^{-5}–10^{-3} µg m^{-3} have been recorded in unpolluted areas and increasing to 0.003–0.18 µg m^{-3} in urban areas and greater than 1 µg m^{-3} close to industrial plants (13).

2. Anthropogenic sources:
Man releases arsenic into the air, water and soil in his utilization of natural resources . Arsenic may accumulate in soil by use of arsenical pesticides, application of fertilizers, dust from the burning of fossil fuels, disposal of industrial and animal wastes (14).
Average concentration of As in Indian coal industry area ranges up to 3.72 mg/kg, with a maximum value of 40 mg/kg (15). Hence, it is believed that coal combustion in Eastern India is

one of the major sources of anthropogenic As emission in the environment. There are several metallurgical plants, cement factories, incineration and chemical industries in eastern India which contribute to the emission of As into the environment. However, there are no data on the exact tonnage of As entering the environment. A secondary lead industry near greater Kolkata, West Bengal, releases As to the environment and maximum concentration in soil of the area is reported to be 9740 ± 226 mg/kg; the minimum is 17.5 ± 0.52 mg/kg (16).

1.Arsenic contamination in different water bodies in West Bengal:

Though presence of large quantity of water resources in West Bengal but the major problem arsenic has been found in many natural waters including seawater, ground water, rivers, and lakes. Most arsenic in natural water is a mixture of arsenate and arsenite. Thus, arsenic can mix into lakes, rivers, or underground water by dissolving in rain or snow, or through the discharge of industrial wastes (17). Some of the arsenic will mix to the sediment on the bottom of the lake or river, and some will be carried along by the water (17). As concentrations in sediments from the river Ganges averaging 2.0 (range 1.2 – 2.6) mg kg^{-1}, from the Brahmaputra river averaging 2.8 (range 1.4 – 5.9) mg kg^{-1} (11) .

A large part of the Bengal delta basin bound by the rivers Bhagirathi is affected by arsenic contamination of groundwater of geogenic origin the exact sequence of geochemical reactions releasing arsenic from the aquifer sediments is still debated**.** The contaminated areas are located mainly to the east of the Bhagirathi River, West Bengal (5). Some affected areas also occur over the Damodar fan-delta (18).

Now a days the ground water is used for aquaculture (19).Since arsenic can be accumulated in aquatic organisms (20).Use of high arsenic content groundwater for aquaculture has resulted in an accumulation of arsenic in cultured animals, such as fish. The first report of arsenic groundwater contamination and its health effects, in the Ganga plain from West Bengal was published in 1984 (21). Based on the intensity of arsenic concentrations West Bengal is devided into three zones: highly affected, mildly affected, and unaffected. The highly affected districts (Maldah, Murshidabad, Nadia, North-24-Parganas, South- 24-Parganas, Bardhaman, Haora, Hugli and Kolkata), in which an arsenic concentration of <300 µg/l. Five districts (Koch Bihar, Jalpaiguri, Darjeeling, Dinajpur- North and Dinajpur-South), showing concentrations mostly below 50 µg/L but none above 100 µg/l are known as mildly affected. The five other districts (Bankura, Birbhum, Purulia, Medinipur East and Medinipur West) are unaffected or arsenic safe (22).

The pond water arsenic concentration of contaminated villages varied widely.The ponds receiving ground water and aquaculture effluents had significantly high arsenic accumulation and seasonal variations were found statistically insignificant. In West Bengal it was reported that total arsenic content of pond water 62 ± 52 µg l^{-1} (range: 15 - 221 µg l^{-1}) (23). The range 4 – 70 µg l^{-1} from limited numbers of ponds from contaminated villages of Nadia District, West Bengal, India (24).

The average arsenic contaminated in West Bengal aquatic field are given in table-2.

Table 2- Average arsenic concentrations in West Bengal water bodies:

Source	**Arsenic (µg As/l)**
Rivers	0.20-264
Lakes	0.38-1.00
Sea Water	2.15-6.00
Ponds	4-70
Canals	40-150

Source: ICAR (2003)

Bioaccumulation of arsenic in Aquatic Organism:

Bioaccumulation refers to the net accumulation of a chemical by an aquatic organism as a result of uptake from all environmental sources (e.g., water, food, sediment). Bioaccumulation is the result of competing rates of chemical uptake and elimination by aquatic organisms. BAF is the

ratio (in L/kg) of the concentration of a chemical in the tissue of an aquatic organism to its concentration in water under steady condition, in situations where both the organism and its food are exposed. (25). The BAF is calculated as:

$$BAF=C_t/C_w$$

where:
Ct = concentration of the chemical in wet tissue (either whole organism or specified tissue)
Cw = concentration of chemical in water

The bioaccumulation of arsenic in freshwater-cultured fish (tilapia and shrimp) was measured to assess the risks to human health (26).

Arsenic Effect on Fish:

Arsenic is one of the most toxic elements to fish .Acute exposures can result in immediate death.The fish exposed to arsenic have difficulty breathing due to the clogging of gills by coagulated mucous film and to the direct damage of arsenic ions on blood vessels, resulting in vascular collapse in the gills and anoxia (27).

Besides the organs already mentioned also the liver and the kidney exhibit a strong accumulation of radioactive arsenic immediately after the feeding of radioactive arsenic was discontinued. The strong concentration of arseno organic compounds in the eyes and in the throat and gills, that is in the most pronounced mucus membrane regions show that these compounds may have a bacteriostatic effect and is used by the fish to protect these area against micro-organisms (28).The effect of arsenic in various fish species are describe in table 4.

Table 4-Effect of Arsenic in Defferent Fish Species (NIWQP 1998)

Fish	As Compound	Effect
Thymallus arcticus	As(III)	96-h LC50 for juvenile & alevin
Black crappie (*Pomoxis nigromaculatus*)	Total As	Decrease fish growth
Brown bullhead (*Ameiurus nebulosus)*	‘’	As = 0.9 mg/kg (ww) in flesh
Chinook salmon fry (Oncorhynchus tshawytscha)	As(III)	Irregular growth & decrease weight
Midas cichlid (Cichlasoma citrinellum	Total As	No effect. As in fish muscle<0.01%0.37mg/kg (ww)
Jaguar guapote (Cichlasoma Managuense)		No effect. As in fish muscle <0.01%0.24 mg/kg (ww)
Eel (Angulia australis)	Total As	As = 0.4 mg/kg (ww) in flesh
Pallas (*Notopterus notopterus*	As (III)	50% mortality in 43h
Perch (Perca Fluviatilis)	Total As	As = 0.3%0.5 in flesh; 0.2 in scales(mg/kg, ww)
Rainbow trout *(Oncorhynchus mykiss)*	As (III) ,Sodium arsenate	1.Reduced weight gains after 8 weeks. 2.Some adaptation to dietary As observed, as initial negative growth gave way to slow positive growth over time.
Rainbow trout larvae	As(III)	1% mortality (in moderately hard water of pH 6.9%7.8).
Rudd *(Scardinius erythrophthalmus)*	Total As	As <0.2 mg/kg (ww) in flesh, liver, and brain.
Channa punctatus	As(III)	Growth of fingerlings of freshwater murrel was significantly reduced.

Anabas testudineu	Sodium arsenate	Mortality of Fish increase
Clarias gariepinus	Total As	Toxic effects of arsenic on body indices, blood parameters, carbohydrate metabolism .
zebrafish (*Danio rerio*)	sodium arsenate	Decrease Development of Zebrafish Embryos
Labeo rohita	As(V)	biochemical changes in the liver tissues

CONCLUSION

Arsenic contamination in the riverine system or the aquatic bodies occurs either due to mining, pesticides or because of chemical wastes added in the aquatic source from geomorphological processes. The contamination of arsenic from geomorphological sources are predominant in certain district of West Bengal. Arsenic is known for its toxic and fatal effects in some of the communities permanently dependent on water from riverine systems or their long and short stagnation sources. Moreover, arsenic is known to affect the biological potential of aquatic animals.

On the basis of the review it can be concluded that fishes are also able to synthesise both fat soluble and water soluble arseno organic compounds from the inorganic arsenic to be found in the feed eaten by the fish. However, this inorganic arsenic plays an insignificant role as source for the organic bound arsenic found in fish. An accumulation of arseno organic compounds in specific organs shows that the compounds may possibly have a significance for fish. Inorganic arsenic present in the water will also be absorbed by the fish, but neither water soluble nor lipid soluble. Since the average fish consumption of the resident population is low compared to the contaminated drinking water and rice, the exposure from fishes is relatively less.

ACKNOWLEDGEMENT

Thanks to my teacher Dr.Kausik Mondal, Astt. Professor, Dept. of Zoology, Sidho-Kanho-Birsha University, Purulia to encourage me and providing all necessary facilities for conducting this study.

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