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Research paper

Assessment of bioaccumulation factor for heavy metals in Bansagar dam regarding fish tissue on Son River Deolond

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Abstract: The concentrations of heavy metals (Cu, Zn, Fe, Pb and Hg) were measured in water and the Muscles, liver, gills, kidney and gonad of fish species collected from Bansagar dam, Deolond in central India. The levels of heavy metals varied significantly among fish species and organs. Muscles possessed the lowest concentration of metals. The essential metals as Cu were accumulated mainly in liver and gonad, Zn accumulated mainly in Gills and Liver, Fe were accumulated in all organs with little bit fluctuation in concentration while Pb accumulated in gill, liver and gonad and Hg exhibited their highest concentrations in gonads. The concentration of metals in the present fish organs within the permissible limits given by WHO and FAO but in case of Hg and Pb these are higher than the limits. BAF for observed metals also showed highest level of metals accumulation in Gill, liver, kidney and gonad than muscles. The Bioaccumulation Factor values of the heavy metals analyzed in this study showed that bioaccumulation has occurred in the fish in the alarming rate and fishes found in this dam are not suitable for human consumption it may cause severe health threats without proper treatment.

Keywords: Heavy metals, Bansagar dam, Fishes, health threats, Bioaccumulation Factor

Introduction:

The pollution of the aquatic environment with heavy metals has become a worldwide problem in recent years, because they are indestructible and most of them have toxic effect on organisms (Mac Farlane and Burchett, 2000). In the recent years, world consumption of fish has increased simultaneously with the growing concern of their nutritional and therapeutic benefits. In addition to its important source of protein, fish typically have rich contents of essential minerals, vitamins and unsaturated fatty acids (P. Kris-Etherton, W. Harris, L. Appel, 2002).The American Heart Association

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recommended eating fish at least twice per week in order to reach the daily intake of omega-3 fatty acids. However, fish are relatively situated at the top of the aquatic food chain; therefore they normally can accumulate heavy metals from food, water and sediments (F. Yilmaz, N. Ozdemir, A. Demirak, A.L. Tuna, 2007).

In the last few decades, the concentrations of the heavy metals in fish have been extensively studied in different parts of the world (K.J. Elnabris, S.K. Muzyed, N.M. El-Ashgar, 2013).Most of these studies concentrated mainly on the heavy metals in the edible parts that is fish muscles however other studies reported the distribution of metals in different organs like the liver, kidney, hearts, gonads, bone, digestive tract, gills and brain. The content of toxic heavy metals in fish can counteract their beneficial effects and may cause many adverse effects on human health this may include serious threats like renal failure, liver damage, cardiovascular diseases and even death (M. Al-Busaidi, P. Yesudhason, 2011 and M.S. Rahman, A.H. Molla, 2012).

Heavy metals are implicated in neurological disorders especially in the foetus and in children, which can lead to behavioural changes and impaired performance in intelligent quotient (IQ) test (Landner and Lindestrom, 1998).The quality of the ecosystem has been degrading due to agriculture and human activities. Fish is an important component of the human diet in many villages and cities in Shahdol division of central India and Bansagar Dam is the very enormous source of fish culture and transportation of fishes to different region of Shahdol division and other places too, for this reason, the results obtained from the study would provide information on background levels of metals in the fish species of the river Sone, contributing to the effective monitoring of both environmental quality and the health of organisms inhabiting the river ecosystem.

It is therefore very important for study to be conducted on the concentration of heavy metals in the tissues of fishes of river Sone in Bansagar dam at Deolond in central India and check whether or not the concentration levels are within the permissible limits for human consumption in comparison to safety reference standards for the consumption of fish. Because in this area many people are dependent on fish as a food, especially fisher mans and it may cause severe health hazards.

Materials and Methods:

Fish Sampling

12 water samples and 24 commercial fish samples were used for study in three seasons of the year summer, winter and rainy, during two years (from 2015-16 to 2016-17) from every site. The collected species were *Labeo rohita, Labeo calbasu, Notopterus notopterus and Channa punctatus*. These fish species represent different biotopes and are economically important. Collected fish were immediately preserved in an ice box and transferred to the laboratory where they were classified, weighed, measured by total length and kept frozen at −20 °C until further analysis. The fish and water samples collected from the different sites and analyzed at laboratory. Atomic Absorption Spectrophotometer (AAS) was used for the determination of the heavy metals in the tissue and water samples.

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Map showing sampling site (Bansagar Dam)

Determination of Metal Concentrations

Preparation of subsamples and analysis were made for metal analysis, frozen fish were partially thawed and each fish was dissected using stainless steel instruments. Muscles, Liver, Gills, Kidney and Gonad were taken out and dehydrated it, in oven, composite samples of 2–5 g were used for subsequent analysis.

The samples were digested with ultra pure nitric acid at 100°C until the solution become clear. The solution was made up to known volume with deionized distilled water and filtered, using 0.45 micron Filter paper with the help of swinex and analyzed for Cu, Zn, Pb, Fe and Hg using the Atomic Absorption Spectrophotometer (AAS model ELICO, SL-168) the obtained results were expressed as mg/kg.

Heavy metals Cu, Zn, Pb, Fe and Hg concentration in water also measured using the Atomic Absorption Spectrophotometer (AAS model ELICO, SL-168), the obtained results were expressed as ppm (mg/l).

Determination of bioaccumulation factor

Bioaccumulation of metal occurs through uptake and retention of a substance from water through body surfaces and gill membrane. Bioaccumulation factor was determined by the ratio of metal concentration in organ and its concentration in the water, according to Kalfakakour and Akrida-Demertzi, 2000.

BAF = M tissue/M water.

Where; M tissue is the metal concentration in fish tissue mg/kg and M water, metal concentration in water mg/L.

Statistical Analysis

Results were generally expressed as mean ± standard deviation and one way ANOVA test was used to compare the data among seasons at the level of 0.05.

Observations

Concentrations of heavy metals (Cu, Zn, Pb, Fe and Hg) in the muscles, liver, gill, kidney and gonad of fish collected from the different sites of Bansagar Dam. As shown in Table-01, the contamination levels of these five metals were high in tissues.

Specially, the concentration of Hg and Pb exceeding, FAO and WHO target values. Consumption of water as well as fish may create health problems related with Hg and Pb contamination may occur in human beings.

The accumulation of metals in a single species showed significant inter-specific

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variations in all metals. However it can be noticed that, different organs exhibited different patterns in metals accumulation. In other words, no single type of fish showed the highest metals in all organs. Therefore, concentrations of metals between species were analyzed in single organ; all results showed significant variations between species. Furthermore, some fish from the same species collected from different sites also significantly accumulated different concentrations of metals. Variations of metals distribution in the studied fish can be summarized as the following:

FISH SPECIES	ORGANS	Cu	Zn	Fe	Hg	Pb
Labeo rohita	Muscles	0.000±0.000	0.921±0.001	1.754±0.011	1.836±0.021	0.852±0.012
	Liver	3.513±0.001	1.465±0.002	2.112±2.001	0.408±2.011	2.969±0.065
	Gills	1.084±0.001	1.505±0.001	2.023±1.002	1.642±0.001	3.241±0.002
	Kidney	3.250±0.000	1.326±0.002	1.541±0.003	1.210±0.012	2.542±0.015
	Gonad	2.350±0.002	1.420±0.013	2.324±0.013	0.921±0.031	3.074±0.011
Labeo calbasu	Muscles	0.000±0.000	0.769±0.003	1.927±0.032	1.248±0.021	2.102±0.027
	Liver	2.920±0.002	0.986±0.101	2.077±0.002	1.889±0.001	2.992±0.045
	Gills	0.000±0.000	0.910±0.002	2.424±0.011	0.921±0.011	1.245±0.033
	Kidney	0.000±0.000	0.420±0.011	2.775±2.002	0.226±0.002	2.421±0.012
	Gonad	3.173±0.002	0.479±0.014	2.776±0.011	1.320±0.006	3.221±0.008
Notopterus notopterus	Muscles	2.566±0.003	1.136±0.003	2.200±0.005	0.091±0.001	2.924±0.042
	Liver	3.288±0.000	1.625±0.032	2.411±0.012	1.532±0.041	2.920±0.020
	Gills	1.229±0.002	1.666±1.011	1.358±1.006	0.881±0.062	3.074±0.078
	Kidney	1.020±0.000	1.201±1.000	2.101±0.008	0.982±0.015	2.241±0.059
	Gonad	2.001±0.001	1.521±0.013	1.520±0.009	1.642±0.031	3.991±0.033
Clupisoma garua	Muscles	1.624±0.000	1.424±0.022	1.586±0.005	0.523±0.072	2.958±0.084
	Liver	2.410±0.002	1.650±0.031	1.603±1.021	0.661±0.001	3.243±0.007
	Gills	1.360±0.001	1.623±0.003	2.052±1.020	0.101±0.023	3.054±0.001
	Kidney	1.423±0.003	1.522±1.002	2.001±0.002	0.441±0.003	2.043±0.002
	Gonad	2.101±0.002	1.422±0.012	1.531±1.008	1.210±0.045	3.221±0.011

Table 01: Table showing mean (±SD) concentrations of heavy metals (mg/kg) in some organs of fish species collected from Bansagar Dam.

	Cu	Zn	Fe	Pb	Hg
FAO/WHO limit(2011)	30	40	43	0.5	
*FAO(1983)	30	30	---	0.5	
**WHO 1989	30	100	100	2	
***FSAI(2009)	-	-	-	0.3	
****FSSAI(2011)	30	50		2.5	
ANSG	0.5			0.5	1.0
EU Regulation1881/2006/EU				0.30	0.5
European Commission Decision 93/351/EEC					0.5

*Food and Agriculture Organization, **World Health Organization
***Food Safety Authority of Ireland, ****Food Safety and Standard Authority of India
ANSG- Australian national seafood (fish, molluscs and crustaceans) guidelines for heavy metals

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Heavy Metals	Cu	Zn	Fe	Pb	Hg
Summer	ND	0.131±0.014	0.844±0.002	0.742±0.023	3.602±0.009
Rainy	ND	0.087±0.008	0.807±0.000	0.889±0.012	3.537±0.003
Winter	ND	0.061±0.011	0.779±0.000	0.732±0.021	3.130±0.006
Average	**0.00**	**0.093±0.011**	**0.810±0.002**	**0.788±0.019**	**3.423±0.006**

Table-03:-Table showing mean (±SD) concentrations of heavy metals (ppm) in water collected from Bansagar Dam, Shahdol district (Sone River).

Fish Species	Organs	Zn	Fe	Hg	Pb
Labeo rohita-1	Muscles	09.903	2.165	0.157	1.081
	Liver	15.753	2.607	0.035	3.768
	Gills	16.183	2.498	0.480	4.113
	Kidney	14.258	1.902	0.353	3.226
	Gonad	15.269	2.870	0.270	3.901
Labeo calbasu-2	Muscles	08.269	2.380	0.365	1.944
	Liver	10.602	2.564	0.552	3.797
	Gills	09.785	2.993	0.270	1.580
	Kidney	04.516	3.426	0.066	3.073
	Gonad	05.151	3.427	0.386	4.088
Notopterus notopterus-3	Muscles	12.215	2.716	0.027	3.711
	Liver	17.473	2.977	0.448	3.706
	Gills	17.914	1.677	0.257	3.901
	Kidney	12.914	2.594	0.287	2.844
	Gonad	16.355	1.877	0.480	5.065
Clupisoma garua-4	Muscles	15.312	1.958	0.153	3.754
	Liver	17.742	1.979	0.193	4.115
	Gills	17.452	2.533	0.030	3.876
	Kidney	16.366	2.470	0.129	2.593
	Gonad	15.290	1.890	0.353	4.088

Table-04:-Table showing bioaccumulation factors of heavy metals in fishes collected from Bansagar Dam, Shahdol district (Sone River).

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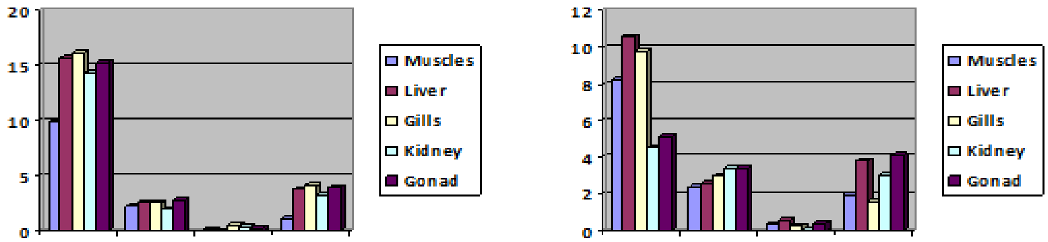
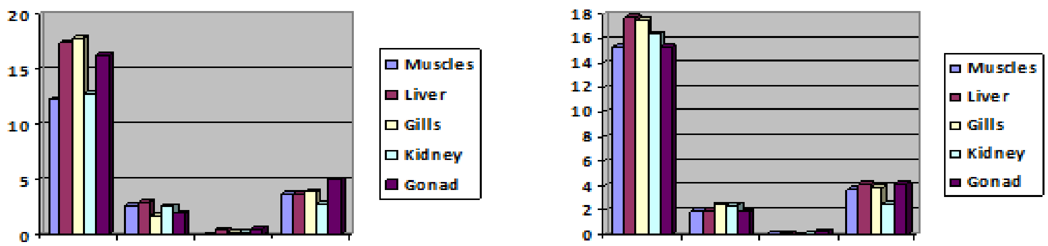


1-2



3-4

Graph showing BAF for different metals in different organs of different four fishes

Heavy Metals Analysis in tissues

Copper (Cu)

The copper concentration in the tissues of *Labeo rohita* is 0.00, 3.513±0.001, 1.084±0.001, 3.250±0.000, and 2.350±0.002 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Labeo calbasu* are 0.00, 2.920±0.002, 0.00, 0.00, and 3.173±0.002 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Notopterus notopterus* 2.566±0.003, 3.288±0.000, 1.229±0.002, 1.020±0.000, 2.001±0.001 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Clupisoma garua* are 1.624±0.000, 2.410±0.002, 1.360±0.001, 1.423±0.003, 2.101±0.002 in Muscles, Liver, Gills, Kidney, and Gonad respectively.

Zinc (Zn)

The Zinc concentration in the tissues of *Labeo rohita* is 0.921±0.001, 1.465±0.002, 1.505±0.001, 1.326±0.002, and 1.420±0.013 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Labeo calbasu* are 0.769±0.003, 0.986±0.101, 0.910±0.002, 0.420±0.011, and 0.479±0.014 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Notopterus notopterus* 1.136±0.003, 1.625±0.032, 1.666±1.011, 1.201±1.000, 1.521±0.013 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Clupisoma garua* are 1.424±0.022, 1.650±0.031, 1.623±0.003, 1.522±1.002, 1.422±0.012 in Muscles, Liver, Gills, Kidney, and Gonad respectively.

Iron (Fe)

The Iron concentration in the tissues of *Labeo rohita* is 1.754±0.011, 2.112±2.001, 2.023±1.002, 1.541±0.003, and 2.324±0.013 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Labeo calbasu* are 1.927±0.032, 2.077±0.002, 2.424±0.011, 2.775±2.002 and 2.776±0.011 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Notopterus notopterus* are 2.200±0.005, 2.411±0.012, 1.358±1.006, 2.101±0.008, and 1.520±0.009 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Clupisoma garua* are 1.586±0.005, 1.603±1.021, 2.052±1.020, 2.001±0.002, and 1.531±1.008 in Muscles,

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Liver, Gills, Kidney, and Gonad respectively.

Mercury (Hg)

The Mercury concentration in the tissues of *Labeo rohita* is 1.836±0.021, 0.408±2.011, 1.642±0.001, 1.210±0.012 and 0.921±0.031 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Labeo calbasu* are 1.248±0.021, 1.889±0.001, 0.921±0.011, 0.226±0.002, and 1.320±0.006 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Notopterus notopterus* are 0.091±0.001, 1.532±0.041, 0.881±0.062, 0.982±0.015, and 1.642±0.031 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Clupisoma garua* are 0.523±0.072, 0.661±0.001, 0.101±0.023, 0.441±0.003, and 1.210±0.045 in Muscles, Liver, Gills, Kidney, and Gonad respectively.

Lead (Pb)

The Lead concentration in the tissues of *Labeo rohita* is 0.852±0.012, 2.969±0.065, 3.241±0.002, 2.542±0.015 and 3.074±0.011 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Labeo calbasu* are 2.102±0.027, 2.992±0.045, 1.245±0.033, 2.421±0.012, and 3.221±0.008 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Notopterus notopterus* are 2.924±0.042, 2.920±0.020, 3.074±0.078, 2.241±0.059, and 3.991±0.033 in Muscles, Liver, Gills, Kidney, and Gonad respectively. In *Clupisoma garua* are 2.958±0.084, 3.243±0.007, 3.054±0.001, 2.043±0.002, and 3.221±0.011 in Muscles, Liver, Gills, Kidney, and Gonad respectively.

Heavy Metal Analysis in water

The Zinc, Iron and Mercury concentrations in the water are highest in the summer season (0.131±0.014, 0.844±0.002, 3.602±0.009) whereas lowest concentrations are found in winter season (0.061±0.011, 0.779±0.000, 3.130±0.006).Lead is found in highest concentration in Rainy while lowest in winter. Copper (Cu) is one of the metal, which are essential to human health. It’s presence in the aquatic environment may be due to accumulation of domestic and agricultural wastes but we did not found this metal in Dam water. The higher concentration of Zn in this study could be associated with human activities and vehicle (boat) movement that occur in the environment. Human activities such as the use of chemicals and Zinc based fertilizers by formers could also enhance a high concentration of this metal in soil and water. It is an essential mineral of importance to both plants and animals.

Lead level recorded in this study is due to its relatively toxicity which can be probably due to contamination of the river by the activities of fisherman’s and paints which is used to colour the boats. In this study, lead levels were above the recommended limits (0.1ppm) for water. Pb is a toxic element, which has no significant biological function and shows their carcinogenic effects on aquatic biota and humans even at low exposures. Pb exposure is known to cause musculo-skeletal, renal, ocular, neurological, immunological, reproductive and developmental effects. Mercury is a highly toxic element that is found both naturally and as an introduced contaminant in the environment. The concentration of Hg in water is highest than prescribed limits by WHO, Indian Council of Medical Research (mg/l) and BIS, IS: 10500- Desirable (mg/l) (0.001ppm). In present study mining, fertilizers and domestic waste products are main reasons of Mercury contamination which is responsible for the many health hazards in population living across the Dam.

Bioaccumulation factor

The concentration of chemicals in aquatic organism can be calculated by Bioconcentration factors and Bioaccumulation factors. Both factors demonstrate the partitioning of a chemical between water and aquatic organisms (often fish) at abiding state conditions.BCF refers to levels in organisms only due to uptake of surrounding water whereas BAF refers to levels in organisms not only due to uptake from the surrounding water from food also.

BCF in animals can therefore only be measured in laboratory studies, where uptake from food can be restricted, whereas the ratios measured in field are BAF.Bioaccumulation factors are commonly used in assessment models, as they provide a pollution-scale independent parameter. Bioaccumulation factors are easy to calculate. In aquatic systems the factors are usually expressed in the unit L/kg based on concentrations measured as mg/kg and mg/L, respectively. Although, it is known that bioaccumulation factors (BAF) for a given element vary widely among organisms as well as environments, they are often treated as spatially and temporally constants.

In our study *Labeo rohita* showed, BAF for Zn and Pb were higher in Liver, Gills, Kidney and Gonad than Muscles. Highest BAF for Zn (16.183**)** and Pb (4.113**)** were noticed in Gills. BAF for Fe were found equally distributed in all organs as well as BAF for Hg were higher in gills (0.480**)** and kidney (0.353**)** than other organs.

In *Labeo calbasu*, BAF for Zn (10.602) and BAF for Hg (0.552) were found highest in Liver. BAF for Fe were maximum in Kidney (3.426) and Gonad (3.427) as well as Pb BAF showed higher level in Gonad (4.088).

In *Notopterus notopterus*, BAF for Zn were found maximum in Liver (17.473) and Gill (17.914). BAF for Fe were found equally distributed in all organs whereas BAF for Hg (0.480) and Pb (5.065) were highest in gonads.

In *Clupisoma garua,* BAF for Zn were about to equal in all organs ranges from 15 to 17 and BAF for Hg were found highest in Liver(0.193) and gonad(0.353). BAF for Fe were about to equal as well as Pb BAF showed highest level in Gonad (4.088**)** and liver (4.115**)**.

Discussions:

The Bioaccumulation Factor values of the heavy metals analyzed in this study showed that bioaccumulation has occurred in the fish in the alarming rate. The phenomenon that different metals are accumulated at different concentrations in the various organs of fish was observed in this study (Edward J. B.-2013).The difference in the levels of accumulation in the different organs/tissues of a fish can primarily be attributed to the differences in the physiological role of each organ, regulatory ability, behaviour and feeding habits **(**Marzouk M.-1994).

Present study showed the lowest concentration of metals in muscle. The essential metals as Cu were accumulated mainly in liver and gonad, Zn accumulated mainly in Gills and Liver, Fe were accumulated in all organs with little bit fluctuation in concentration while Pb accumulated in gill, liver and gonad and Hg exhibited their highest concentrations in gonads.

The accumulation of metals in liver is probably linked to its role in metabolism (S. Zhao, C. Feng, 2012) high levels of Cu and Zn in hepatic tissues are usually related to a natural binding proteins such as metallothioneins (Gorur FK, Keser R, 2012) which act as an essential metal store as Zn and Cu to fulfil enzymatic and other metabolic demands (Roesijadi G.,1996, Amiard JC,2006) while Fe tends to accumulate in hepatic tissues due to the physiological role of the liver in blood cells and haemoglobin synthesis (Gorur FK, Keser R, 2012).On the other hand, the liver also showed high levels of non-essential metals such as Pb to displace the normally metallothioneins associated metals in hepatic tissues(Amiard JC,2006).previous studies also show similar trends to accumulate high level of essential and non-essential metals in liver cells in fishes(S. Zhao, C. Feng,2012, Eisler R.,2010, Amundsen PA,1997, Jose U,2004, Dural M,2007)

Presence of these metals in gills shows that gills are main route of metal ion exchange from water (Qadir A, 2011) as they have large surface area and facilitate rapid diffusion of toxic metals (Dhaneesh KV, 2012).Therefore it is suggested that metals accumulated in gills are mainly concentrated from water specially Pb and Zn, previous studies also show the similar things as Kargin (1998), Avenant-Oldewage and Marx (2000), Abu Hilal and Ismail (2008), Qadir and Malik (2011) and Eisler (2010)

It is well known that muscles are not active site for metal biotransformation and accumulation (Elnabris KJ, 2013) but in polluted aquatic habitats the concentration of metals in fish muscles may exceed the permissible limits for human consumption and imply severe health threats.

Conclusions:

The concentration of metals in the present fish organs within the permissible limits given by WHO and FAO but in case of Hg and Pb these are higher than the limits. So health risk analysis of heavy metals in the edible part (muscle) of the fish indicated safe levels for human consumption and concentrations in the muscles are generally accepted by the international legislation limits however in some areas of this region people consume whole fish with all organs specially small size fishes and the ovary is consumed by many people's so study reveals that fishes found in this dam are not suitable for human consumption it may cause severe health threats.

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