

Heavy metal contamination of fish with relation to water quality of Narmada River, Madhya Pradesh

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Abstract

The Narmada also called Rewa is the third holy and fifth largest west flowing river of India and biggest west flowing river of the state Madhya Pradesh. The river takes its origin from Maikal hillocks from eastern highlands of Vidhyas ranges near Amarkantak, district Shahdol (M. P.) at an elevation of 1051 meters (Gazetteer of Hoshangabad 1979). Optimum fish production is greatly dependent on the physical, chemical and biological qualities of water. Hence, successful fish management requires an in-depth understanding of water quality. A study to assess heavy metal (Cr, Cd, Mn, Pb and Zn) contamination and physicochemical parameters of water samples from four selected stations in Narmada River was conducted. The parameters included temperature, pH, salinity, total hardness, electrical conductivity (EC), chemical oxygen demand (COD) and biological oxygen demand (BOD). The results revealed detectable Mn and Zn levels in all the selected sites; with Mn levels in three areas being significantly higher than the World Health Organization (WHO) recommended limit (< 0.500 mg/L). Of the three samples, which showed detectable Cr and Cd levels, concentrations of two exceeded the permissible limits. Pb was below the detection limit in all the samples whilst Cu levels detected in two of the sites were below the permissible limit. The investigated physicochemical parameters had the following ranges: temperature C, pH 5.8-8.2, BOD 0.3-20 mg/L, Total Dissolved Solids (TDS) 37-249–26-29 mg/L, EC 73.67-498 μ S/cm, total hardness 0.8-5.7 mg/L, salinity 0.03-0.22 psu and COD 2.9-9.7 mg/L. Most of these values were within WHO recommended levels. The findings suggest that regular monitoring of the heavy metal load is necessary to guard against long-term effects of its presence in the water, influencing fish and human uptake.

Keywords: *Heavy metals, Physicochemical analysis, Chemical oxygen demand, Biochemical oxygen demand, Narmada River, Bioaccumulation*

Introduction

The valley of the river Narmada has been the seat of an uninterrupted flow of human civilization dating from pre-historic times. The Narmada finds mention as one of the seven most sacred rivers in ancient Indian texts. A number of written accounts and ballads refer to this river. The river Narmada has supported a variety of people and diverse socio-cultural practices ranging from the relatively autonomous adivasi (tribals) settlements in the forests to non-tribal rural population. Due to the various anthropogenic activities the aquatic biodiversity of Narmada river is declining day by day. The threat of global climate change is pervasive across all of the earth's ecosystems and is also often cited as a major threat to freshwater biodiversity.

The challenge of providing food and livelihood to a population well over 9 billion people by the middle of the twenty-first century has been enormous for human societies (FAO, 2018). Food and agriculture are key to addressing this global challenge and fisheries and aquaculture directly linked to many Sustainable Development Goals (SDGs). More importantly, SDG 14 seeks to conserve and sustainably use the oceans, seas and marine resources. According to the FAO Director-General, Jose Graziano da Silva,

(2018), since 1961 the annual global growth in fish consumption has been twice as high as population growth, demonstrating that the fisheries and aquaculture sector is crucial in meeting the FAO's goal of a world without hunger and malnutrition. The Food and Agriculture Organization (FAO) further estimates that almost 20 % more fish will be eaten by 2030. Although fish supply will increase in all regions, the per capita fish consumption is anticipated to decrease in Asia, a concern for food security on the continent. Aquaculture is a fairly good business in Madhya Pradesh, and its pattern is growing across the country, especially, in the northern and southern region. The operators pattern on a subsistence scale applies semiintensive and extensive systems to culture fish in earthen River, dams, dugouts, River and reservoirs (Amenyogbe et al., 2018). Holding systems used by these farmers are floating cages, earthen River and concrete tanks. Fish feed generally includes cereal bran such as wheat bran, rice bran and maize bran which are commonly accessed from the local market. It is established that fish productivity in aquaculture largely depends on feed consumption and quality (Sandre et al., 2017); stocking density (M'balaka et al., 2012), biotic factors such as sex, age, and genetic variance, and abiotic factors such as water chemistry, temperature, photoperiod (Makori et al., 2017) and oxygen level (Bhatnagar and Devi, 2017). Therefore, an understanding of water quality, which is determined by abiotic factors such as temperature, dissolved oxygen (DO), transparency, turbidity, water color, carbon dioxide, pH, alkalinity, hardness, unionized ammonia, nitrite, nitrate, biological oxygen demand (BOD), plankton population among others is essential for the effective management of Narmada River. Water is the natural habitat of fishes and other aquatic organisms, and in fish farming, water quality is vital for optimal production and fish welfare; especially when done in an artificial setting (Mandal et al., 2017; Oluyemi et al., 2010). According to Boyd (1990), water quality is the most important limiting factor in fish culture. Water quality parameters that are commonly measured and monitored to maintain the health and well-being of fish include temperature, pH, alkalinity, dissolved oxygen (DO), carbon dioxide, ammonia, hardness, nitrites and total dissolved solids (TDS) (Jaeger and Aubin, 2018; Sehar et al., 2014). Each of these factors has a standard value for fish culture and can directly or indirectly affect fish health (James, 2000). While some parameters such as alkalinity and hardness are relatively steady, others like dissolved oxygen and pH vary regularly. Fluctuations in some parameters may affect other parameters. For instance, pH is interdependent with other parameters such as alkalinity and hardness (Klontz, 1993). The quality of a fish River is also affected by pollutants from anthropogenic activities such as metals, pesticides and other chemicals released into the environment and ultimately in water bodies (Biney, 1986). Recent studies show that fish accumulate heavy metals from food, water and sediments (Adeyeye, 1996). Although some of these heavy metals in their right concentrations are beneficial, others can be toxic to aquatic organisms and humans. For example, zinc is an essential element and plays a vital role in maintaining cytoplasmic veracity. However, at higher concentrations, zinc causes structural damages to fish that affects their growth and survival. In humans, high concentrations of zinc can cause skin annoyances, stomach cramps, vomiting, nausea, damage to the pancreas and disturbed protein metabolism (Sehar et al., 2014). Although the most common water sources used for aquaculture are wells, springs, rivers and lakes, some people also practice artificial fish farming. Artificial fish farming is generally done in River controlled to achieve optimum fish production conditions (Eze and Ogbaran, 2010). In this study, heavy metal contamination and water quality parameters suitable for optimum fish production in Narmada river was investigated and compared with standard values for fish culture.

Material and Methods

Study area

The Narmada also called Rewa is the third holy and fifth largest west flowing river of India and biggest west flowing river of the state Madhya Pradesh. The river takes its origin from Maikal hillocks from eastern highlands of Vidhyas ranges near Amarkantak, district Shahdol (M. P.) at an elevation of 1051 meters (Gazetteer of Hoshangabad 1979). The basin covers large areas in the states of Madhya Pradesh

(86%), Gujarat (12%) and a comparatively smaller area (2%) in Maharashtra. The Narmada empties itself in the Gulf of Cambay in Gujarat. Nearly 90% of the flow is in M. P. and most of the remaining is in Gujarat. It flows for a very brief stretch through Maharashtra. The soil is enriched with minerals that support the cultivation of staple foods such as yam, cocoyam, maize etc.

Sampling

Water samples from four sampling site were randomly taken weekly for three weeks and analyzed. At each location, the samples were taken twice or thrice. Whilst some parameters were measured onsite, others were performed in the laboratory.

Physicochemical analysis

The temperature, conductivity, salinity, pH and total dissolved solids of the various samples were measured directly onsite using a Hanna HI 9829 multiparameter meter. Measurements for each parameter were taken according to the manufacturer’s instructions. The chemical oxygen demand, biological oxygen demand and turbidity were determined as reported by APHA (1992).

Heavy metal analysis

The concentrations of manganese, cadmium, copper, chromium, lead and zinc were analyzed using atomic absorption spectroscopy (AAS) after the samples had been digested following standard procedures reported in the literature (Sehar et al., 2014; Mensah et al., 2016). Typically, 5 ml of HNO₃ was added to 100 ml of the water sample in a 250 ml beaker. The resultant mixture was heated until the volume reduced to approximately 20 ml. Digestion was continued by heating and adding of HNO₃ until a clear solution was obtained. The solution was cooled and filtered into a 50 ml volumetric flask and made up to the mark. A blank solution was prepared with the same procedure without the sample. Analysis for concentrations of Mn, Cu, Zn, Cr, Pb and Cd was done with Atomic Absorption Spectrometer (Analytik Jena: NovAA 400 P) in replicate and the standard deviations determined.

Results and Discussion

Heavy metals Metals are released into water bodies from natural sources as well as human activities (Sehar et al., 2014). Despite the adverse effects of metals on the environment, some are essential to living organisms. These metals are of particular interest due to their adverse effects and ability to bioaccumulate in aquatic ecosystems (Soylak and Erdogan, 2006). Fishes in the human diet are considered as a rich source of essential metals (iron, zinc, copper) and polyunsaturated fatty acids (predominantly omega-3 fatty acids) (Sehar et al., 2014). There is, therefore, the need to ensure that fishes are wholesome for human consumption. The presence and concentrations of six heavy metals were analyzed in all the eight River. The results are summarized in Table 1.

Table-1: Heavy metal concentrations in waters of three ecosystems (mg/l)

Premonsoon	Li	Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga
	0.09±0.01	BDL	1.43±0.19	0.003±0	0.003±0	0.03±0	0.12±0.01	BDL	0.002±0	0.01±0	0.02±0	BDL
	0.02±0.005	BDL	1.18±0.27	0.002±0.0001	0.001±0.0001	0.05±0.004	0.12±0.006	0.002±0	0.001±0	0.01±0	0.02±0.002	BDL
	BDL	BDL	4.32 ±0.27	0.01 ±0	0.004 ±0	0.18 ±0.04	0.65 ±0.06	0.01 ±0	0.01 ±0	0.13 ±0.02	0.07 ±0.01	0.001 ±0
Monsoon												
	0.08±0	BDL	4.19±0.34	0.005±0	0.001±0	0.07±0	0.18±0.02	BDL	0.002±0	0.02±0.002	0.04±0.006	BDL
	0.09±0.02	BDL	2.89±0.19	0.004±0	0.001±0	0.05±0.01	0.18±0.009	BDL	0.001±0	0.02±0.004	0.03±0.006	BDL
	0.009 ± 0	BDL	12.05 ± 0.63	0.02 ± 0	0.007 ± 0	0.43 ± 0.02	10.02 ± 1.5	0.001 ± 0	0.01 ± 0	0.12 ± 0.01	0.10 ± 0.01	0.002 ± 0
Post monsoon												
	0.03±0.007	BDL	0.05±0.003	0.003±0	0.002±0	BDL	0.003±0	0.001±0	0.003±0	0.01±0.002	BDL	BDL
	0.03±0.003	BDL	0.06±0.01	0.003±0	0.001±0	0.04±0.004	0.001±0	0.001±0	0.001±0	0.01±0	BDL	BDL
	0.002±0	BDL	0.07±0.007	0.003±0.001	0.0003±0	0.03±0.01	0.004±0	0.0003±0	0.004±0	0.06±0.01	BDL	BDL

The results revealed detectable levels of Mn and Zn in all the selected sites. Mn concentration ranged from 0.03 to 0.07 mg/L with monsoon season recording the highest whilst Zn was between 0.0122 and 0.440 mg/L (Table 1). Aside from Mn, Cd, and Cr in a few of the sites where the observed concentrations

were higher, the values reported in this study are generally comparable to similar studies (Adeyemi and Ugah, 2017; Onuoha, 2017).

Carcinogen raises a serious concern about its high levels. However, Pb was not detected in any of the samples whilst copper was detected at some sites with concentrations of 0.0108 and 0.0233 mg/L, respectively, which were within the WHO permissible limits. The undetected levels of Pb and low levels of Zn and Cu notwithstanding, these metals are known to bioaccumulate and biomagnifies within the different trophic levels in the food chain. Benthic and pelagic fish have been reported to bioaccumulate Zn, Pb, Cd and Cu in gills, liver and flesh (Rahman et al., 2012). Zn bioaccumulation in the gills and biomagnification in the food chain have equally been reported (Sehar et al., 2014).

Metals such as Cr, Pb and Cd are non-essential and bioaccumulate in tissues and body of aquatic organisms in higher concentration than in the water (Abumourad et al., 2013; Healey, 2009). This causes serious health problems in humans. For instance, cadmium can bind with proteins to form complexes that can distort the purifying property of the kidney (Sastry and Gupta, 1979). The detection of Cd and Cr in some water samples pose a threat to both the aquatic organisms and humans. A possible contamination source could be the runoff from adjacent agricultural areas since these metals are often present in fertilizers or pesticides.

Table-2: Physico-chemical characteristics of fresh water.

Parameters	Pre monsoon	Monsoon	Post monsoon
pH	7.6 ± 1.87	6.62 ± 1.61	6.81 ± 1.23
Temp (°C)	27.5 ± 2.59	25.6 ± 4.94	23.6 ± 1.84
Ec (µs/cm)	660 ± 36.96	500 ± 101.50	724 ± 121.63
Salinity (ppt)	0.3078 ± 0.01	0.2332 ± 0.06	0.337 ± 0.03
DO (mg/l)	7.9 ± 0.69	8.8 ± 2.22	7.6 ± 1.23
BOD (mg/l)	3.2 ± 0.22	1.95 ± 0.48	2.29 ± 0.36
TS (mg/l)	1004.45 ± 213.95	868.61 ± 81.65	882.4 ± 80.30
TDS (mg/l)	960 ± 220.80	850 ± 214.20	816 ± 187.68
TSS (mg/l)	44.45 ± 6.36	18.61 ± 4.58	21.4 ± 3.06
Cl ⁻ (mg/l)	186 ± 21.84	122 ± 11.47	116 ± 13.92
TH (mg/l)	182 ± 32.76	204 ± 15.91	210 ± 37.80
Ca H (mg/l)	24.5 ± 4.46	19.7 ± 3.31	23.86 ± 1.86
Mg H (mg/l)	157.5 ± 38.27	184.3 ± 18.06	186.14 ± 31.27
TA (mg/l)	204 ± 39.37	163 ± 26.41	182 ± 17.84

Temperature

Like amphibians and reptiles, fishes are coldblooded, implying they tend to have the same body temperature as the surrounding water. Fishes have poor tolerance to temperature. At higher water temperatures, water holds less dissolved oxygen, and this affects fish respiration and metabolism. This causes stress and a high mortality rate (Boyd, 1990; Chang et al., 2019; Devi et al., 2017). The temperature of the Narmada River analyzed in this study ranged (Table 2), which were within the range (from 26 to 29 °C). These temperatures recommended by WHO (15-30 °C) have been confirmed by research earlier reported in the literature (Zanatta et al., 2010).

pH

The pH of water is an index of hydrogen ion activity of water. A drop or rise of one pH unit indicates a ten-fold increase or decrease in hydrogen ion concentration. pH has also been found to vary at different times of the day in surface water systems; low before sunrise and highest in the middle of the day (Kestemont et al., 2015). The pH values of the investigated Narmada River ranged from 5.80 to 8.20 over the three weeks (Table 2). According to Swingle (Swingle, 1967) and Hephher and Pruginin (Hephher and Pruginin, 1981), a pH range of 6.62 to 7.6 at daybreak is considered best for fish culture. Even though fishes may survive at a pH as low as 4 or as high as 11, fish production would drastically reduce (Devi et al., 2017). River had lower pH values required for optimum fish production in the third week of sampling. This can be due to waste deposit (eg: decaying organic matter) in the River and can cause a high rate of fish mortality.

Electrical Conductivity

The conductivity of water is simply the measure of how well it conducts electricity. Although WHO has no guideline for EC in River, Stone and Thomforde (2004), reported that electrical conductivity of 30-500 $\mu\text{S}/\text{cm}$ is acceptable for River fish culture. From the results, the EC for the entire River were within the acceptable levels. Since conductivity is directly related to the concentration of conductive ions in water, increasing the amount of dissolved salts and inorganic materials like chlorides, sulphate and carbonate compounds would increase the electrical conductivity. Aside from electrical conductivity being the basis for salinity and TDS calculations, it is useful in monitoring early water system changes (Langland and Cronin, 2003).

Salinity

Salinity is a major feature that affects the density and population growth of aquatic organisms (Jamabo, 2008). The amount of salt dissolved in a water body is defined as the total concentration of electrically charged ions present in the water. Salinity, therefore, contributes enormously to the electrical conductivity of the water. The values obtained for the Narmada River fell within the standard range of 0-1.0 psu recommended by WHO.

Total dissolved solids

The value of TDS for the various River ranged from 37 to 249 mg/L as reported in Table 2. River A1 and A2 have the least dissolved substances. This is consistent with the low EC values for the said River. All these values were within the permissible values for water qualify for Narmada River.

Hardness

Total hardness is simply a measure of the calcium and magnesium concentrations in water. Even though other di and tri-valent ions may contribute to total hardness, they are mostly present in insignificant quantities. From the results, an appreciable decrease in total hardness was observed in the third week of sampling. Overall, the values obtained in the study were below the standard range of 50– 100 mg/L suitable for aquaculture as recommended by the WHO, which implies that the water is soft. It has been reported that total hardness values less 20 mg/L can cause stress and less mineral content in fishes (Dinesh et al., 2017). This can, however, be corrected by liming the River.

BOD and COD

BOD is the measurement of the amount of dissolved oxygen needed by organisms to break down the organic matter present in a given water sample under aerobic conditions at a specific temperature over a certain period. According to Boyd and Thunjai (2003), the standard range of BOD suitable for most freshwater species is between 3 and 20 mg/L. The BOD of the various ranged from 0.3 to 2.0 (Table 2). The values recorded were all below the lower limit. This could be as a result of overstocking of fish in the River causing a shortage of oxygen. Low dissolved oxygen concentration has been noted as a major cause of stress, poor appetite, slow growth, disease susceptibility and mortality in aquaculture animals (Makori et al., 2017). The BOD of the River, however, can be increased by using mechanical aeration (Warish et al., 2017). The COD values ranging from 2.9 to 9.7 mg/L were within WHO's recommended values.

Earlier research on the COD for Narmada River has reported values less than 20 mg/l (Warish et al., 2017).

Conclusions

The water quality of selected Narmada River in MP has been studied. Based on the findings, temperature, salinity, COD and TDS were all found to be in the optimum range recommended for fish growth in all the four sampling areas whilst total hardness and BOD were below the acceptable range. The presence of heavy metal such as chromium and cadmium in some of parts of the River pose a health risk to aquatic organisms and humans. The present study suggests that appropriate steps be undertaken at the investigated River to maintain and improve the water quality for fish culture at regular intervals and monitor the effect of these changes on the fish's growth. This would help ensure the well-being of the aquatic biome, humans and the environment.

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