

# Metal Trace Element Concentration in Commercial Fish Species from Vembanad Backwater System: Evaluating the Risks of Human Consumption

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**Abstract** This study was carried out to provide information on Metal Trace Element concentrations in the muscles, gills, and liver of five commercial fish species available in Vembanad backwater systems and to evaluate the possible risk associated with their consumption. The concentration of Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), and Zinc (Zn) were determined in *Etroplus suratensis*, *Mughil cephalus*, *Scatophagus argus*, *Epinephelus areolatus*, and *Elops machnata*. The liver and gills showed higher metal concentrations than the muscles. The concentration of MTEs was analysed using Inductively Coupled Plasma Mass Spectrometry. The mean maximum heavy metal levels in the muscles were as follow; Zn (62.12 µg/g)>Cr (30.17 µg/g)>Cd (29.62 µg/g) >Cu (23.47 µg/g)>Ni (20.95 µg/g)>Pb (18.34 µg/g) respectively. Human health risk levels from fish consumption were assessed using multiple indices like Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index, and Carcinogenic Risk (CR). The Carcinogenic values for Cd, Pb, Ni, and Cr were calculated and evaluated in all species, while CR values calculated for all 6 elements did not pose a risk, it was found above the threshold value of 10<sup>-4</sup>. THQ for both adult and children consumers were <1 indicating no hazard from consumption. In addition, Since HI is <1 it has been concluded that the consumption of fish species will not pose a potential health risk.

**Keywords:** fish, heavy metals, human health risk, ICP-MS, Vembanad Backwater System

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## 1. Introduction

In recent years, fish consumption has increased simultaneously with the growing concern about their nutritional and therapeutic benefits. In addition to its essential source of protein, fish typically have rich contents of excellent sources of omega-3 fatty acids, vitamins, selenium, and calcium, and are increasingly consumed by humans [1]. [2] Studies have been reported that in 2008, 115 million tons of fish were consumed with an average of 17 kg per capita. As fish contribute an important part of the human diet it is not that surprising. The concentration of Metal Trace Elements (MTEs) in fish have been studied in past several decades. Studies have shown that the accumulation of MTEs in fish occurs with respect to various factors like metal type, fish species, and tissues respectively [3]. MTEs have become a serious concern in the majority of major metropolises due to their toxicity even at deficient concentrations, persistence in the environment, and capacity to accumulate in fish tissues.

These are metallic elements that have a density greater than 5g/cm<sup>3</sup>. These metals occur naturally in the environment but can also be released into the ecosystem through various human activities. Although some of the metals are essential as micronutrient, their high concentration in the food chain cause toxicity and environmental impacts [4]. Metals such as zinc and copper are classified as essential metals due to the fact that they play a role in biological systems. On the other hand, metals such as lead, and cadmium become toxic in small quantities and are therefore non-essential metals. Non-degradable nature of MTEs plays a major role in making them persistent pollutants. Our environment receives these MTEs through various anthropogenic activities like industrial emissions, domestic wastes, sewage, acid mine drain, and stormwater. The ecological risks posed by these MTEs when they enter the food chain depend mainly on the quantity and partitioning of metals present in water and sediments; metal speciation and solubilization. Aquatic species get irreversibly mutilate due to the toxicity and bioaccumulation nature of MTEs released into the water body. Fish can accumulate a large number of toxicants and

are considered bioindicators to monitor MTEs in the aquatic environment [5]. As at the top of the food chain in the aquatic system, fish can accumulate a substantial quantity of MTEs through gill, surface skin, and oral ingestion of food and water [6]. Accumulation of MTEs above the maximum permissible limit can cause changes in blood composition, impaired development, and reproduction [7,8], renal failure, liver damage, cardiovascular diseases, and even death [9,10]. Therefore, many international programs for monitoring and controlling of MTEs that negatively affect public health have been established.

Vembanad backwater, situated on the southern part of the western coast of India, is highly polluted due to industrial effluents, insecticide usage in agricultural fields, urban sewage, and soil erosion caused by deforestation in the highland areas. The ecosystem is an essential source of Livelihood for thousands of fishermen and supports a wide range of aquatic flora and fauna. The backwater system is also a vital tourist destination, attracting millions of visitors every year. However, the ecosystem is facing numerous environmental challenges due to various human activities. The rapid industrialization and urbanization in the region have led to discharge of various toxic pollutants into the backwater system. More than 60% of industries in Kerala, including the chlor-alkali industry, are situated on the banks of the Vembanad backwaters [11]. Rapid industrial growth and economic development have occurred around the lake since the 1980s [12]. Studies have been reported that Vembanad lake was moderately polluted by MTEs based on their study of sediments, whereas increased nutrient inputs related to population and economic growth have led to eutrophication. The increased level of pollution and eutrophication leads to the degradation of water quality, loss of biodiversity and decline in fish stocks. Most pollutants come from rivers discharging into the lake. Since the study area is considered an important source of the fishery the presence of toxic MTEs in water and sediments would be the primary source for the biomagnifications of metals in fish, invertebrates, and other aquatic plants animals and cause ill effects to those who consume the contaminated fish [13]. The present study aims to evaluate the concentration of MTEs in commercially important fish species from the Vembanad backwater system. The objective of the present study is to (i) determine the MTEs accumulation in muscle, gill, and liver tissues of sampled fish commonly consumed by the people of that region, (ii) toxic risk level assessment, (iii) investigate the relationship between heavy metal concentrations in fishes using Pearsons Correlation Coefficient.

## 2. Materials and Methods

### 2.1. Study Area

Vembanad lake, one of the three Ramsar sites in Kerala, Southern part of India having an area of 151,250 ha is the largest brackish water, humid tropical wetland system. Seven rivers (Manimala, Meenachil, Pamba, Achankovil, Muvattupuzha, Periyar, and Chalakudy) which originate in the Western Ghats Biodiversity Hotspot, drain the largest estuarine system on the south-west coast of India. The

system opens into the Arabian Sea in Cochin and Munambam. The major hydrological variable in the backwater is Salinity. Salinity gradient supports diverse species of flora and fauna depending on their capacity to tolerate all conditions. The lake benefits the people that live along its shores. Fishing, tourism, coir retting, inland navigation, lime shell, and agriculture are some of the occupations they are employed in. The potential of the aquatic system, which previously supported high levels of bio productivity and biodiversity, has been negatively impacted by recent alterations made to the estuary, such as reclamation and the subsequent reduction of the backwater and the discharge of pollutants.






### 2.2. Field Sampling

Sampling was conducted during the pre-monsoon period (January – May). Fish samples have been collected randomly from different locations, recognized as a popular fishing point of the lake. They were purchased from fishermen within the bank of the study area after interaction and confirming the location of the catch with respect to each sampling station. Samples were washed with deionized distilled water and stored in pre-cleaned plastic bags and kept frozen in an ice box for transportation. The samples were stored at -20°C for further analysis.

### 2.3. Sample Extraction and Analysis

Five commercially importance fish species, *Etroplus suratensis*, *Mughil cephalus*, *Scatophagus argus*, *Epinephelus areolatus*, and *Elops machnata*, were selected for the present study from the catch. 7 specimens of each species were collected for analysis. Standard taxonomic manuals and keys from the fisheries survey of India and worms [14] were used to identify the specimens. Morphometric data of each fish were measured. The photos of the studied fish along with length and weight are given in Table 1. Prior to analysis, frozen fish samples were partially thawed and dissected using stainless steel scalpels. Using clean equipment, the gills, liver, and muscle tissues were dissected and oven-dried at 90°C. 200 mg of dried sample is weighed and digested using 10ml triacid (9:2:1), i.e., (nitric: sulphuric: perchloric acid), and the sample was made up to 10 ml using deionized distilled water and filtered with a syringe filter of pore size 0.22µm and directly analyzed [15]. After digestion, the samples were analyzed using Perkin Elmer ICPMS (model NexIonTM 300X). The Instrument Parameter used during the analysis included a nebulizer gas flow rate of 15 L/min, a spray chamber temperature of 2°C, and a mass spectrometer setting of m/z 45-238. Calibration was performed using a series of standard solutions (multi element standard, conc 100mg/L) containing known concentrations of the target analytes, and quality control measures were taken by analyzing blank solutions and spiking samples with certified reference materials. The methodology involved performing 3 cycles of 30 seconds each, and recording the signal intensity for each analyte in triplicate. The resulting data was then analyzed using signal intensity to calculate the concentration of each analyte, normalizing the data using the internal standard, and correcting for matrix effects using a calibration curve based on the spiked samples.

Table 1. Average body weight and length of selected Fish Samp

Fish	Length (cm)	Weight(g)	Image
<i>Etroplus suratensis</i>	22.75	0.238	
<i>Scatophagus argus</i>	27.675	0.208	
<i>Mughil cephalus</i>	18.5	0.150	
<i>Elops machnata</i>	26.4	0.253	
<i>Ephinephelus areolatus</i>	28.15	0.205	

**2.4. Estimation of Metal Pollution Index (MPI) in Fish Species**

MPI was calculated to examine total heavy metal pollution in various tissues of different species. MPI for each species calculated using following equation:

$$MPI = (M_1 \times M_2 \times M_3 \times \dots \times M_n)^{1/n} \quad (1)$$

where Mn is the concentration of metal expressed in microgram per gram [16].

**2.5. Health Risk Assessment**

In this study, the human health risk from metals in the edible muscle parts of the examined species was assessed with EDI, THQ, HI, and CR. Health risk assessments were carried out independently for adults and children because children are considered to be more sensitive to pollutants than adults.

**2.5.1. Daily Intake (EDI)**

MTEs in fish species were calculated using the concentration of metal in fish in mg/kg. The estimated daily intake of MTEs was determined according to the following equation

$$EDI = \frac{DFC \times C}{WAB} \quad (2)$$

Where DFC = daily food consumption, C = metal concentration in the fish sample, and WAB = Average body weight. In the present study, the regional daily consumption rate for fish in adult as well as in children were not available yet, therefore daily consumption rate of fish in children and adult were considered to be 57.5g/day and 92.6g/day and the average body weight used for Indian man and children are 55.9kg and 32.7 kg [17].

**2.5.2. Target Hazard Quotient (THQ)**

The health risk associated with the consumption of fish species were assessed based on the Target Hazard Quotients and calculations were made using the standard hypothesis of an integrate [18].

$$THQ = \frac{E_{fr} \times ED_{tot} \times FIR \times C}{RfD_o \times BW_a \times AT_n} \times 10^{-3} \quad (3)$$

Where EF = exposure frequency (365 days/year) [19], ED = exposure duration (65 years) [20], FIR= Food Ingestion Rate (57.5g/person/day for children and 92.6g/person/day for an adult), C = metal concentration in fish tissues in mg/kg, RfD = Oral reference dose in mg/kg/day. As per the [21,22], the oral reference dose for Cd, Cr, Cu, Ni, Pb, and Zn were 0.001, 0.003,0.3,0.02,0.004 and 0.3 correspondingly, WAB = Average body weight (55.9 kg for adult and 32.7 kg for children) [17], TA = exposure time for noncarcinogens (EF×ED). The acceptable guide value for THQ is “1” [21]. If the THQ Value is less than 1, the exposed population is unlikely to experience an

adverse health hazard. Conversely, if the THQ value is greater than 1, there is a potential health risk.

### 2.5.3. Hazard Index (HI)

Hazard Index is the sum of the hazard quotients for all metals observed [23]. The equation is as follows:

$$HI = \sum_{i=1}^n THQ_i \quad (4)$$

Where THQ is the risk values of multiple elements from fish samples [18]. HI values higher than 1 refers that consumers will experience significant non-carcinogenic health risk effects [7].

### 2.5.4. Carcinogenic Risk (CR)

Carcinogenic risk is the incremental probability of cancer in an individual, over a lifetime due to exposure to a substantial carcinogen [19]. The CR is calculated by the multiplication of the carcinogenic slope factor of the metal contents [24] and the equation is as follows

$$TR = \frac{E_{fr} \times ED_{tot} \times FIR \times C \times CSF_o}{BW_a \times AT_c} \times 10^{-3} \quad (5)$$

Where TA represents the mean exposure period for carcinogens (365days/year  $\times$  ED) and the CSFo is the oral carcinogenic slope factor derived from the Integrated Risk Information System (Cr:0.5; Ni:1.7; Pb:8.5 $\times 10^{-3}$ ; Cd:6.3 mg/kg/day) [24].

## 2.6. Statistical Analysis

The data were statistically analyzed using the statistical package IBM SPSS 22. The means and standard deviations, of the metal concentrations in fish samples were calculated using SPSS 22 and other calculations were performed by Microsoft excel 2013.

## 3. Result and Discussion

### 3.1. Metal Concentration and Accumulation in Fish Species

Heavy metal contamination in fish is one of the severe threats to humans and aquatic animals among the brackish fish species, a varied assortment of MTEs concentrations was noted. In this study most commonly consumed fishes from the region are selected. Seven species of each fish were obtained and used to determine the MTEs concentration. The concentration of selected metals (Cd, Cr, Cu, Ni, Pb and Zn) in various fish species were presented in Table 2.

The Cd concentration in analyzed fish samples varied from 24.62  $\mu\text{g/g}$  to a maximum of 36.32 $\mu\text{g/g}$ . Among the species and the organs analyzed, maximum and minimum concentration was recorded in the gills (36.32 $\mu\text{g/g}$ ) and liver (24.62) of *E. suratensis*. The measured mean concentration of Cd in all the fish muscles are in the following order: *E. suratensis* > *S. argus* > *M. cephalus* > *E. machnata* > *E. areolatus*. [25] reported that the

agricultural runoff from the catchment of the lake could be a potential source of Cd as the use of fertilizers and pesticides in agriculture can introduce cadmium into the soil. The concentration of Cu in fish muscles varied between 29.42  $\mu\text{g/g}$  and 30.03  $\mu\text{g/g}$  with an average of 29.624  $\mu\text{g/g}$ . according to [26,27], the maximum permissible limit of Cd for human consumption is 50  $\mu\text{g/g}$  and all the tissues analyzed are under the permissible limits.

Cr levels recorded in muscles, gills, and liver of different species were 95.36,101.64 and 81.69 for *E. suratensis*, 17.98, 28.64, and 22.61 for *M. cephalus*, 12.22,19,19.06 and 15.56 for *S. argus*,11.70,17.65 and 22.16 for *E. areolatus* and 13.63, 18.64 and 23.01 for *E. machnata*. Cr concentrations in the muscles of *E. suratensis* were determined to be higher than the maximum permissible limits. sources of chromium in lakes could be industrial effluents, domestic sewage [28], untreated municipal sewage, and runoff from agricultural areas [29].

Copper is recognized as an essential element, which plays a major role in cell components having a vital function in all living things. The highest mean concentration of Cu was determined in the gill of *M. cephalus* (76.62 $\mu\text{g/g}$ ) and the lowest was found in the muscle (21.78) of the same species, the maximum permissible limit of Cu is 20 and all the muscle tissue of fishes were under the limits. Industries such as electroplating, pharmaceutical manufacturing, and mining involve the use of copper and these industries may discharge partially treated effluents into the lake [30].

Nickel is a naturally occurring element and its presence in the Vembanad lake could be atmospheric deposition. It can be present in the air as a result of mining, burning of fossil fuels, and other industrial activities [31]. The highest mean concentration of Ni in fish muscle was determined in *E. suratensis* (22.25). The highest Ni concentration of gills and liver of fishes were 14.68 and 18.69 in *E. areolatus*. the average Ni concentrations in this study were found to be below the maximum permissible limits of [26,27].

Pb contamination in the muscles, gills, and liver tissues of fishes was found between 15.32- 26.16  $\mu\text{g/g}$ , 5.01- 31.61  $\mu\text{g/g}$ , and 6.43- 21.04  $\mu\text{g/g}$  respectively. The highest level of Pb was detected in the gills (31.61  $\mu\text{g/g}$ ) of *E. suratensis* and the lowest was detected in the gills (5.0131.61  $\mu\text{g/g}$ ) of *S. argus*. the average Pb concentration in this study was found to be exceeded the maximum permissible limit of [26,27]. Pb in Vembanad lake can be from various industries like battery manufacturing, smelting, and mining. Untreated or partially treated industrial effluents can be significant sources of Pb in lakes [33].

Zn accumulation was higher than all other metals in all sampled fishes when the accumulation number of metals in the muscle tissue is evaluated. The highest Zn concentration was detected in the liver (119.4  $\mu\text{g/g}$ ) of *E. suratensis* and followed by the gills (111.1331.61  $\mu\text{g/g}$ ) of *E. suratensis*. Industrial effluents and other anthropogenic sources are the primary reasons for the heavy metal contamination in the lake [33,34] as well as the natural weathering of rocks and soils in this region [35].

**Table 2.** Mean concentration of analyzed heavy metals ( $\mu\text{g/g}$ ) in muscle, gill and liver tissues of fish samples

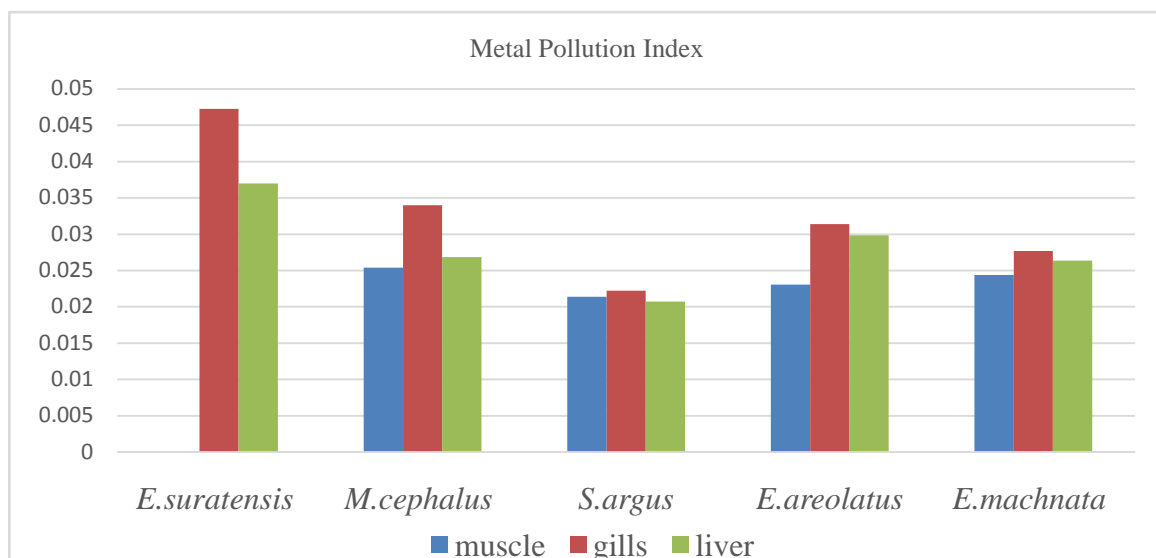
Species	Tissue	Cd	Cr	Cu	Ni	Pb	Zn
<i>E.suratensis</i>	Muscle	30.03±0.002	95.36±1.593	22.97±0.109	22.25±0.143	26.16±0.162	92.79±0.479
	Gill	36.32±2.632	101.64±4.173	69.54±8.21	12.34±0.215	31.61±0.214	111.13±6.543
	Liver	24.62±1.293	81.69±3.982	54.16±9.01	17.64±0.456	11.21±0.231	119.4±4.532
<i>M.cephalus</i>	Muscle	29.54±0.006	17.98±0.141	21.78±0.117	20.46±0.107	15.57±0.013	72.43±0.510
	Gill	32.41±1.534	28.64±0.415	76.62±3.117	11.06±0.456	20.36±0.465	96.32±0.239
	Liver	26.11±0.763	22.61±0.151	28.64±0.415	18.41±0.217	11.04±0.263	109.21±5.321
<i>S.argus</i>	Muscle	29.65±0.005	12.22±0.044	22.61±0.151	20.78±0.085	16.39±0.020	34.11±1.315
	Gill	31.43±0.117	19.06±0.619	65.09±6.52	13.64±1.765	5.01±0.11	45.31±4.786
	Liver	27.96±0.271	15.56±0.778	31.54±0.278	16.64±0.785	6.43±0.213	54.22±0.542
<i>E.areolatus</i>	Muscle	29.42±0.005	11.70±0.058	23.82±0.225	20.30±0.154	15.32±0.036	59.05±0.491
	Gill	32.41±0.754	17.65±0.712	62.98±2.43	14.68±0.564	24.98±0.148	72.34±0.167
	Liver	26.11±0.342	22.16±0.732	36.66±2.451	18.69±0.764	21.04±0.172	84.65±0.332
<i>E.machnata</i>	Muscle	29.48±0.003	13.63±0.031	26.17±0.092	20.97±0.103	18.26±0.081	52.26±0.358
	Gill	30.44±0.116	18.64±0.791	67.62±2.721	13.06±0.654	13.62±0.119	65.81±0.428
	Liver	27.11±0.345	23.01±0.892	31.09±1.114	17.04±0.267	6.64±0.128	74.36±0.117

### 3.2. Ecological and Human Health Risk Assessment

The present study analyzed the MPI for Cd, Cr, Cu, Ni, Pb, and Zn in the studied fish species, and the obtained results are shown below (Figure 1). If the value is less than 2, it is considered that the degree of pollution is not impacted, while the values varied between 2 and 5, observing very low contamination and the value ranged from 5 to 10 deals with low contamination [36]. MPI was calculated for the gills, liver, and muscles of each fish species. The values calculated from the gills were more than that in the muscles and liver. MPI values analyzed were less than 2 in all the fishes. The highest MPI value (0.045) was found in the gills of *E. suratensis*. The distribution pattern of total concentrations of heavy metal accumulations in the studied fish species follows the order: *E. suratensis*>*M.cephalus*>*E. areolatus*>*E.machnata*>*S. argus* (Figure 1). In recent years *E. suratensis* has been the most consumed and cultured fish in Kerala. Therefore, the high MPI value of *E. suratensis* is a matter of metal contamination-related health hazards to local people.

### 3.3. Estimated Daily Intake

Fish in general have a tendency to accumulate MTEs in their various organs, which can then enter the human metabolism through consumption and pose significant health risks. Therefore, to determine if the metal levels detected in fish samples from the Vembanad lake were safe for human consumption (adults & children), the daily intake of some selected trace metals was assessed and compared with the recommended values (Table 3). Since people consume most of the fish's muscles, this study literally took that into consideration. The highest recorded EDI values were 0.1579 and 0.1676 (mg/day/person) found in Cr for adults and children in *E. suratensis*. The EDI values of children were higher than the EDI values of adults for all the metals. For ingestion, the results in the study area for adults and children were below the recommended daily allowance (RDA), which suggested that the targeted groups of people might experience low or no health effects.

**Figure 1.** Metal Pollution Index in Fish muscles, gills and liver

**Table 3. Estimated Daily Intake of MTEs through consumption**

Elements		Cd	Pb	Ni	Cr	Cu	Zn
RDA (mg/kg/person) *		0.07	0.25	-	0.23	35	-
<i>E. suratensis</i>	Adult	0.049746	0.043335	0.036858	0.157967	0.03805	0.153709
	Child	0.052805	0.046	0.039125	0.167682	0.040391	0.163163
<i>M.cephalus</i>	Adult	0.048934	0.025792	0.033893	0.029784	0.036079	0.119982
	Child	0.051943	0.027378	0.035977	0.031616	0.038298	0.127362
<i>S. argus</i>	Adult	0.049116	0.027151	0.034423	0.020243	0.037454	0.056504
	Child	0.052137	0.02882	0.03654	0.021488	0.039758	0.059979
<i>E. areolatus</i>	Adult	0.048735	0.025378	0.033628	0.019381	0.039459	0.097818
	Child	0.051732	0.026939	0.035696	0.020573	0.041885	0.103834
<i>E. machnata</i>	Adult	0.048834	0.030248	0.034737	0.022578	0.043351	0.08657
	Child	0.051838	0.032109	0.036874	0.023967	0.046018	0.091894

\*[37].

**Table 4. THQ and HI of each metal contaminant in the muscles of selected fishes**

Species	Age Class	THQ						HI
		Cd	Cr	Cu	Ni	Pb	Zn	
<i>E. suratensis</i>	Adult	4.61923E-05	4.88944E-05	1.17775E-07	1.71125E-06	1.00599E-05	4.75767E-07	0.000107451
	Child	4.90333E-05	5.19016E-05	1.25019E-07	1.8165E-06	1.06786E-05	5.12798E-07	0.000114068
<i>M.cephalus</i>	Adult	4.54386E-05	9.21898E-06	1.11674E-07	1.57358E-06	5.98747E-06	3.71374E-07	6.27017E-05
	Child	4.82332E-05	9.78597E-06	1.18542E-07	1.67036E-06	6.35571E-06	4.00279E-07	6.6564E-05
<i>S. argus</i>	Adult	4.56078E-05	6.26563E-06	1.15929E-07	1.5982E-06	6.3028E-06	1.74894E-07	6.00653E-05
	Child	4.84128E-05	6.65098E-06	1.23059E-07	1.69649E-06	6.69044E-06	1.88507E-07	6.37623E-05
<i>E. areolatus</i>	Adult	4.5254E-05	5.999E-06	1.22134E-07	1.56128E-06	5.89133E-06	3.0277E-07	5.91305E-05
	Child	4.80372E-05	6.36796E-06	1.29645E-07	1.6573E-06	6.25366E-06	3.26336E-07	6.27721E-05
<i>E. machnata</i>	Adult	4.53463E-05	6.98858E-06	1.34183E-07	1.61281E-06	7.02191E-06	2.67955E-07	6.13718E-05
	Child	4.81352E-05	1.89065E-05	1.42435E-07	1.712E-06	7.45377E-06	2.88811E-07	7.66388E-05

### 3.4. Target Hazard Quotient (THQ) and Hazard Index (HI)

THQ and HI are the parameters used for the risk assessment and compare the amount of pollutant ingested with a standard reference dose [24]. The THQ and HI estimated for 6 individual trace metals through consumption of studied fish species in adults and children are listed in the table below: The USEPA proposed accepted guideline value for THQ is 1. The highest value of THQ was observed for Cr 4.88944E-05 and 5.19016E-05 For adults and children respectively. THQ values were less than 1 for all five individuals. None of the metals exceeded the hazard quotient threshold. It indicates there is no noncarcinogenic health risk from ingestion of a single trace element through the consumption of these fishes. Thus, we can suggest that these levels of human exposure to the analyzed metals should not cause any deleterious effects. These findings enhanced the necessity of evaluation of HI. HI is the sum of the THQ of each

element studied in individual fish species and an indicator of potential noncarcinogenic risk to humans. The highest HI value (0.000107451 for adults and 0.000114068 for children) was detected in *E. suratensis*.

### 3.5. Carcinogenic Risk

CR values of Cd, Cr, Ni, and Zn were calculated and presented in Table 5. CR values above 10<sup>-6</sup> are considered unacceptable, below 10<sup>-6</sup> are considered insignificant and between 10<sup>-4</sup> and 10<sup>-6</sup> are considered acceptable carcinogenic risks [38]. The measured CR values of Cd, Cr, Pb, and Ni ranged from 0.000285 to 0.000291, 8.99E-06 to 7.33E-05, 2.003E-07 to 3.42E-07, and 5.30E-05 to 5.81E-05 respectively in adults and 0.000302 to 0.000308, 9.55E-06 to 7.78E-05, 2.12E-07 to 3.63E-07, and 5.63E-05 to 6.17E-05 in children. The results showed that children were exposed to higher CRs than adults. But, calculated CR values for both age groups were noted far from the risk as the acceptable range is 10<sup>-6</sup> to 10<sup>-4</sup>.

**Table 5. Carcinogenic risk of each contaminant**

Element	Cd	Pb	Ni	Cr
CSFo*	6.3	10 <sup>-3</sup>	1.7	0.5
	0.00030891	3.63071E-07	6.18E-05	7.79E-05
	0.000303869	2.16094E-07	5.68E-05	1.47E-05
	0.000305001	2.27475E-07	5.77E-05	9.98E-06
	0.000302635	2.12624E-07	5.63E-05	9.55E-06
	0.000303252	2.53428E-07	5.82E-05	1.11E-05

\*[24].

## 4. Conclusion

Heavy metal accumulation in Vembanad Lake is a significant environmental problem that threatens the health and well-being of humans and aquatic life. The accumulation of MTEs in the lake is primarily due to anthropogenic activities such as industrial and agricultural discharges, sewage and waste disposal, and other human activities. The high concentrations of MTEs in the lake can cause various adverse effects, including water contamination, sediments, and biota, bioaccumulation, biomagnification in the food chain, and potential health risks to humans who consume fish or other aquatic organisms from the lake. Efforts should be made to monitor and control the discharge of MTEs into the lake, reduce pollution, and maintain the ecological balance of the lake. This can be achieved by implementing strict regulations, promoting eco-friendly practices, and educating the public about the harmful effects of heavy metals. It is essential to take immediate action to address the heavy metal accumulation in Vembanad Lake to preserve the lake's biodiversity, maintain the ecosystem's balance, and safeguard the health and well-being of the local communities.

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## Statement of Competing Interest

The authors have no competing interests.

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