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Research Article

STUDY ON WATER QUALITY PARAMETERS OF CHALAKUDY RIVER, THRISSUR DISTRICT, KERALA, WITH SPECIAL REFERENCE TO HEAVY METALS

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ABSTRACT

River pollution presents a serious risk to human health, since the chemicals that are present in water have a detrimental impact on aquatic organisms, particularly fish, and have the potential to indirectly damage human health. The present work examined the levels of heavy metals in water samples taken from a variety of locations along the Chalakudy River. The findings of the investigation revealed that the water quality is largely exceptional, with the majority of heavy metal levels being below the permissible limits. Water samples studies at four sites Vettukadav Bridge (CS1), Pariyaram Meloor(CS2), Kombanpara Check Dam (CS3), and Kallur Thekkumuri Pulikkakadavu (CS4) were conducted on this fifth longest river in the state with multiple tributaries. A few km apart, these stations were affected by many local activities including proximity to a warehouse/paper mill(old), a brewery, and a gelatin plant. 12 surface water samples (three from each station) were gathered and examined for heavy metals using AAS. Water quality indicators showed very high TDS levels, which pointed to possible pollution, mineral dissolution, or runoff; temperature, turbidity changes probably affected by seasonal or human activity; low COD and BOD showing little organic pollution. Station CS4, showed the highest concentrations of lead, arsenic, cadmium and iron. Heavy metal analysis in water showed rising concentrations of several metals downstream.

Keywords: Chalakudy river, Pollution, Heavy metals, Human health, BOD.

INTRODUCTION

There are 44 rivers in Kerala, the majority of which have lost some of their purity as a result of human activity. A large rise in the amount of trash produced by industrial processes, particularly heavy metals, has been brought about by the rapid industrialisation and urbanisation that has occurred in recent years (Mathew *et al*.,2022). The Chalakudi River is formed by the confluence of five streams, originating from Anamalai Hills, all these rivers rise at elevations above 470 m. Chalakudi River empties into the right arm of Periyar at Puthenvelikkara. The river derives its name from the Chalakudi town located within its basin. The length of this river is 130 km. Out of the total drainage area of 1,404 sq.km. about 300 sq.km. is in Tamil Nadu. (Padmanabhan, N. 2013). Multiple parameters like pH, hardness, dissolved solids, dissolved oxygen, biochemical oxygen demand etc. are measured to assess water quality. (Jyothi *et al*.,2021). Water pollution, especially by heavy metals (HMs) from urbanization and industrialization, which accumulate in fish and endanger both aquatic and terrestrial life, is emphasized (Fatima *et al*., 2020).

The levels of heavy metals such as lead (Pb), cadmium (Cd), copper (Cu), mercury (Hg), iron (Fe), manganese (Mn), nickel (Ni) etc. are increasing substantially in rivers of Kerala. Heavy metals cause irrevocable damage to the biota, when they are transferred from water bodies to the food chain via assimilation, bioaccumulation and biomethylation processes. (Mathew *et al*., 2022). Heavy metal contamination has an adverse effect on the aquatic, terrestrial, and atmospheric environment as they are not easily degradable. Anthropogenic activities have unwantedly transferred these heavy metals in our food chain and food web. (Hembrom *et al*.,2020). Some heavy

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metals can create toxicity at low level of exposure, and metals like nickel, cadmium and chromium are able to produce carcinogenicity in human. (Gupta *et al*.,2020). Most of the rivers in the urban areas of the developing countries are the ends of effluents discharged from the industries. African and Asian countries are experiencing rapid industrial growth which is making environmental conservation a difficult task. (Agarwal *et al*.,2021). Surface water heavy metal pollution is recognized as one of the most significant environmental dangers (Islam *et al*.,2022).

MATERIALS AND METHODS

Geography of Chalakudy River

Kerala is the state in India where the Chalakudy River (Figure 1) may be found. Additionally, it is referred to as Chalakudy Puzha. There are several major rivers that flow into this river, including Parambikulam, Kuriyarkutti, Sholayar, Karapara, and Anakayam.

Figure 1. Chalakudy river basin physical map.

The Chalakudy River's global source is located at 10 degrees 22 minutes 00 seconds north and 77 degrees 07 minutes 30 seconds east. It is possible to locate the river's mouth at 10 degrees 09 minutes 44 seconds north and 76 degrees 15 minutes 56 seconds east. According to geology, this river is a tributary of the Periyar River. In this context, it is crucial to remember that the government and other organizations view the Chalakudy as a distinct river for all intents and purposes. The elevation of this river is around 1,250 meters (4,101 feet). Its overall drainage area is around 1,704 km2 (658 sq mi), and its length is approximately 145.5 km (90 mi). More precisely, 300 km sq. of the entire drainage area are in Tamil Nadu, and 1404 km sq. are in Kerala. Chalakudy is regarded as more of a Kerala River than a Tamil Nadu river for just this reason. Chalakudy typically discharges 52 m3/s (1,836 cu ft/s) at its mouth (Anish *et al*., 2021). The river originates from Anamalai hills in the Southern Western Ghats, south of Palakkad Gap. (Madhusoodhanan *et al*.,2012). The river is joined by several tributaries that have originated from Parambikulam, Sholayar, Karapara and Kuriyarkutti. Besides the water from the four main tributaries, some other small tributaries also join this river. This river then joins with the Periyar River near Ernakulam and then empties into the Arabian Sea. This river is famous for the two waterfalls namely Athirapally and Vazhachal waterfalls https://kerala.me/environment/lakes-and-rivers/chalakudi.

Description of the study area

The water samples were collected from 4 different locations within the site, all of which were a few kilometres apart. Station 1 is the Vettukadav Bridge, which lies close to the Chalakudi River. Station 2 is Pariyaram Meloor near a warehouse godown and a paper mill is located there in early days. Station 3 is at Kombanpara Check Dam, Pariyaram, close to a brewery industry, and Station 4 is at Kallur Thekkumuri Pulikkakadavu Bridge, close to at gelatin company at Kathikudam village, Kadukutty gram panchayat, Chalakudy block panchayat, Thrissur district, Kerala. This location is beside the Chalakudy River. The Kadukutty gram panchayat is surrounded by the river on three sides: the north, south, and west. (Dwivedi, G. 2011).

Collection and analysis of samples

Chalakudy river is the main location I have chosen for this project. A total of 12 samples were collected from four

different sites. Stations 1, 2, 3, and 4 are the names of the three samples that were collected from each station. Water from the surface was collected in a 100 ml plastic bottle. Advanced instrumentation techniques were used to enable precise and accurate analysis of heavy metals in fish tissues and water.

Analysis for Heavy metals in water samples

Water samples were analysed at MG university using AAS. This methodology outlines the steps involved in detecting heavy metals in water samples using Atomic Absorption Spectrophotometry (AAS).

Sample Collection and Preservation

Collection: Water samples are collected in pre-cleaned, acid-washed polyethylene bottles. The type of bottle depends on the target metals and potential interferences. Preservation: To prevent metal precipitation or adsorption onto container walls, samples are immediately acidified upon collection. Typically, concentrated nitric acid (HNO3) is added to achieve a pH < 2. This step is crucial for maintaining the integrity of the sample and ensuring accurate results. Storage: Samples are stored at 4°C until analysis to minimize biological activity and further chemical changes.

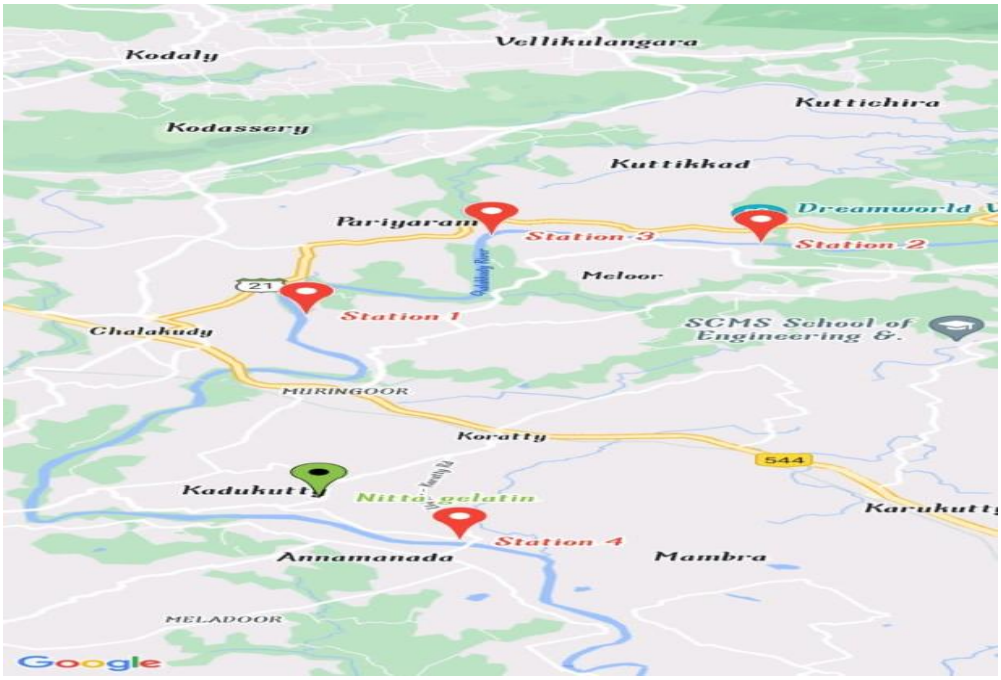

Figure 2. Map of sampling location.

Table 1. Landmark and geographic coordinates of sampling site.

Station	Landmark	Location	Latitude	Longitude
Station 1 (CS1)	Chalakudi River	Vettukadavu Bridge	10.30508°	76.349664°
Station 2 (CS2)	An old paper mill, now ware warehouse godown	Pariyaram, Meloor	10.33085°	76.397689°
Station 3 (CS3)	Brewery industry	Kombanpara Check dam, Pariyaram	10.317126°	76.376278°
Station 4 (CS3)	Near NITTA Gelatin company	Kallur, Thekkumuri , Pulikkakadavu Bridge	10.241139°	76.331158°

Sample Pretreatment (Digestion)

Purpose: Many heavy metals in water samples exist in bound forms (e.g., complexed with organic matter or adsorbed onto particulates). Digestion aims to release these metals into a soluble, ionic form suitable for AAS analysis. Procedure: A known volume of the acidified water sample is transferred to a digestion vessel. Concentrated nitric acid

(HNO3) is added, and sometimes hydrogen peroxide (H2O2) is also used to enhance the oxidation of organic matter. The mixture is heated on a hot plate or in a microwave digester until the sample becomes clear and the volume is reduced Cooling and Dilution: The digested sample is cooled to room temperature and diluted with deionized water to a specific volume. (APHA, 2017).

AAS Analysis

The AAS instrument is calibrated using standard solutions of the target metals. These standards are prepared from certified reference materials and cover a range of concentrations relevant to the expected levels in the samples. The digested and diluted water samples are introduced into the AAS flame. The sample is aspirated into an air-acetylene or nitrous oxide- acetylene flame, where the atoms are excited.

RESULTS AND DISCUSSION

The table (3.1) displays the physico-chemical parameters of the Chalakudy River for the year 2024-25, recorded at four distinct stations (CS1, CS2, CS3, and CS4). These characteristics are essential indicators of water quality, offering insights into the river's health and potential contamination levels. Below is a summary of the principal observations: The temperature at all four sites has a limited range, fluctuating between 23.3 ± 0.12 °C and 24.1±0.23°C. This indicates that temperature remains rather uniform across the measured locations, perhaps mirroring the ambient environmental temperature with little thermal variations. Minor temperature fluctuations may be ascribed to variations in sample time, localised conditions (e.g., shade, flow rate), or negligible anthropogenic effects. measurements vary from 5.56 ±0.32 NTU at CS1 to 8.9 ± 0.09 NTU at CS3, reflecting differences in water clarity. Elevated turbidity at stations CS3 and CS4 indicates a rise in suspended solids, potentially attributable to soil erosion, runoff, or riverbed disturbances. The reduced turbidity at CS1 indicates clearer water, possibly reflecting diminished disturbance or sedimentation in that region. The pH readings exhibit consistency across all sites, ranging from 7.18 ± 0.21 to 7.25± 0.12. This signifies that the river water is predominantly neutral to somewhat alkaline. Minor pH fluctuations may result from natural buffering capability, mineral dissolution, or slight additions of acidic or alkaline substances. Salinity and Total Dissolved Solids (TDS): Salinity readings vary from 0.51 ± 0.03 to 0.94 ± 0.02, and TDS values range from 50.46 ±2.11 to 59.41 ± 2.96. These metrics signify the existence of dissolved salts and minerals in the river water. The elevated salinity and TDS levels at CS4 indicate a higher concentration of dissolved substances at this location, perhaps resulting from enhanced runoff or contributions from adjacent regions. Dissolved Oxygen (DO) levels range from 3.57 ± 0.11 to 4.68 ± 0.33 mg/L among the stations. Dissolved oxygen is essential for aquatic organisms, and these measurements reflect the quantity of oxygen present in the water. Fluctuations in dissolved oxygen (DO) can be ascribed to variables including temperature, organic matter breakdown, and photosynthetic processes. Reduced dissolved oxygen levels at certain locations may indicate elevated organic loads or diminished aeration. Dissolved Carbon Dioxide (DCO2) concentrations vary from 2.61 ± 0.21 to 2.96 mg/L. DCO2 is affected by the respiration of aquatic organisms and the decomposition of organic materials. Fluctuations in DCO2 may be associated with biological activity and the equilibrium between photosynthesis and respiration in the river. The Biochemical Oxygen Demand (BOD) values vary from 4.67 ± 0.32 to 4.76 ±0.21 mg/L. BOD denotes the quantity of oxygen utilised by microorganisms to breakdown organic materials, hence indicating the degree of organic pollution. Consistent BOD values across stations indicate a comparable concentration of biodegradable organic matter in the river. The Chemical Oxygen Demand (COD) values vary from 6.45 ± 0.11 to 7.42 ± 0.21 mg/L. COD quantifies the total oxygen demand necessary to oxidise all organic molecules, both biodegradable and non-biodegradable, hence reflecting the overall organic pollution burden. Minor fluctuations in COD may indicate variations in organic matter composition or the presence of non-biodegradable contaminants at various locations.

Table 2. Physico-chemical parameters of Chalakudy river.

Physico - chemical parameters - Chalakudy river -2024-25										
Station Code	**Temp**	**Turb.**	**Nitrate**	**pH**	**Sali.**	**TDS**	**DO**	**DCO_2**	**BOD**	**COD**
CS1	23.3±0.12	5.56±0.32	0.03±0.01	7.25±0.12	0.51±0.03	50.46±2.11	4.68±0.33	4.76±0.21	2.61±0.03	6.45±0.11
CS2	23.8±0.14	7.67±0.11	0.05±0.01	7.2±0.12	0.68±0.04	54.67±2.11	4.65±0.21	4.67±0.32	2.79±0.03	6.89±0.12
CS3	23.7±0.15	8.9±0.09	0.05±0.01	7.18±0.21	0.83±	55.75±2.3	3.57±0.11	4.69±0.21	2.85±0.06	7.21±0.23
CS4	24.1±0.23	8.12±0.08	0.07±0.01	7.16±0.03	0.94±0.02	59.41±2.96	3.65±0.21	4.75±0.22	2.9±0.08	7.42±0.21
All values are in Mean ± SD form										

Temperature (Temp.) exhibits a robust positive connection with pH (0.988). This indicates that as temperature rises, pH likewise tends to rise dramatically. This may result from temperature- dependent chemical reactions influencing the balance of carbonate species in the water. A robust positive connection is noted with BOD (0.954) and COD (0.903). This suggests that elevated temperatures correlate with heightened biochemical and chemical oxygen demands, perhaps indicating enhanced biological activity and breakdown rates. Turbidity (Turb.) exhibits a moderate positive connection with dissolved oxygen (DO) of 0.792. This implies that elevated turbidity may correlate with augmented dissolved oxygen, potentially attributable to enhanced surface area for oxygen exchange or photosynthetic activity by suspended algae. Weak positive correlations with other measures such as BOD (0.142) and COD (0.119) suggest that turbidity is not a robust predictor of organic pollution in this instance. pH level exhibits a robust positive connection with temperature (0.988). Robust positive relationships with salinity (0.902) and total dissolved solids (0.877) indicate that pH is affected by the concentration of dissolved salts and minerals in the river. Salinity and Total Dissolved Solids (TDS) The connection between salinity and total dissolved solids (TDS) is exceedingly high (0.998), signifying that salinity is a principal element of TDS. Salinity and TDS exhibit robust positive associations with BOD (0.985 and 0.991, respectively) and COD (0.974 and 0.999, respectively), indicating that elevated levels of dissolved salts and minerals correlate with heightened organic pollution (Figure 3 & 4). Dissolved Oxygen (DO) exhibits a moderate positive connection with turbidity (0.792). The weak correlations with BOD (0.802) and COD (0.878) indicate a positive association, albeit weaker than with other metrics. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) have a robust positive connection (0.990), suggesting that the determinants of biodegradable organic matter are intricately linked to those determining total organic pollution. Both exhibit significant connections with temperature, salinity, and total dissolved solids, are stated in (Table 3).

Table 3. Correlation Table of physico- chemical parameters.

	Temp.	Turb.	Nitrate	pH	Sali.	TDS	DO	DCO_2	BOD	COD
Temp.		0.28329	0.011517	0.098256	0.10312	0.030571	0.40346	0.80052	0.04643	0.097447
Turb.	0.71671		0.28108	0.12341	0.14877	0.21747	0.20795	0.42447	0.14289	0.11921
Nitrate	0.98848	0.71892		0.061685	0.059871	0.008125	0.31078	0.90775	0.028175	0.062156
pH	-0.90174	-0.87659	-0.93831		0.001612	0.025518	0.11959	0.82688	0.010642	5.39E-05
Sali.	0.89688	0.85123	0.94013	-0.99839		0.024258	0.11021	0.88302	0.015117	0.002254
TDS	0.96943	0.78253	0.99188	-0.97448	0.97574		0.22764	0.88841	0.008575	0.025967
DO	-0.59654	-0.79205	-0.68922	0.88041	-0.88979	-0.77236		0.98117	0.19784	0.12184
DCO_2	-0.19948	-0.57553	-0.09225	0.17312	-0.11698	-0.11159	-0.01883		0.78378	0.8167
BOD	0.95357	0.85711	0.97183	-0.98936	0.98488	0.99143	-0.80216	-0.21622		0.010095
COD	0.90255	0.88079	0.93784	-0.99995	0.99775	0.97403	-0.87816	-0.1833	0.98991	

Temperature exhibits a robust positive connection with DO (0.80052), BOD (0.95357), and COD (0.90255). Turbidity exhibits a moderate positive connection with DCO2 (0.42447). Nitrate exhibits a robust positive connection with dissolved oxygen (0.90775). The pH has a robust positive connection with Salinity (0.99839), BOD (0.98936), and COD (0.99995). Salinity exhibits a robust positive connection with TDS (0.97574), DO (0.88979), BOD (0.98488), and COD (0.99775). TDS exhibits a robust positive correlation with DO (0.77236), BOD (0.99143), and COD (0.97403). DO exhibits a robust positive connection with DCO2 (0.98117). DCO2 exhibits a robust positive connection with BOD (0.78378) and COD (0.8167). BOD and COD demonstrate a robust positive association of 0.98991(Table 3.2).

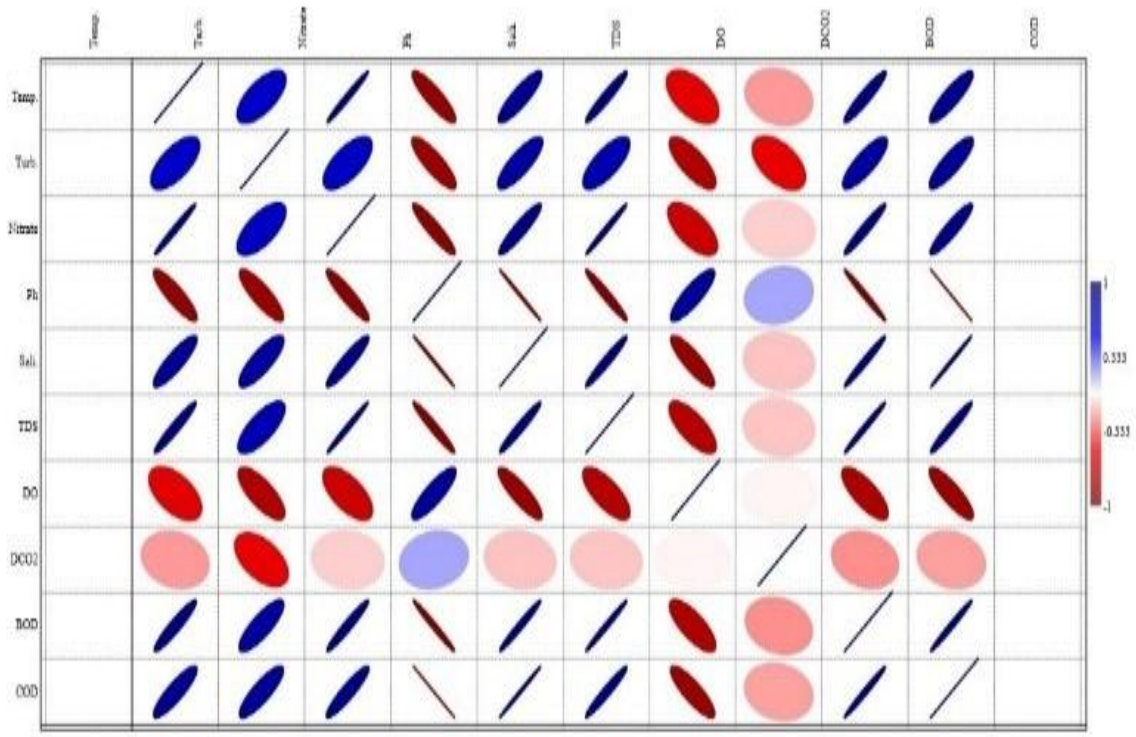

Figure 3. Correlogram showing the correlation of Physico- chemical parameters**.**

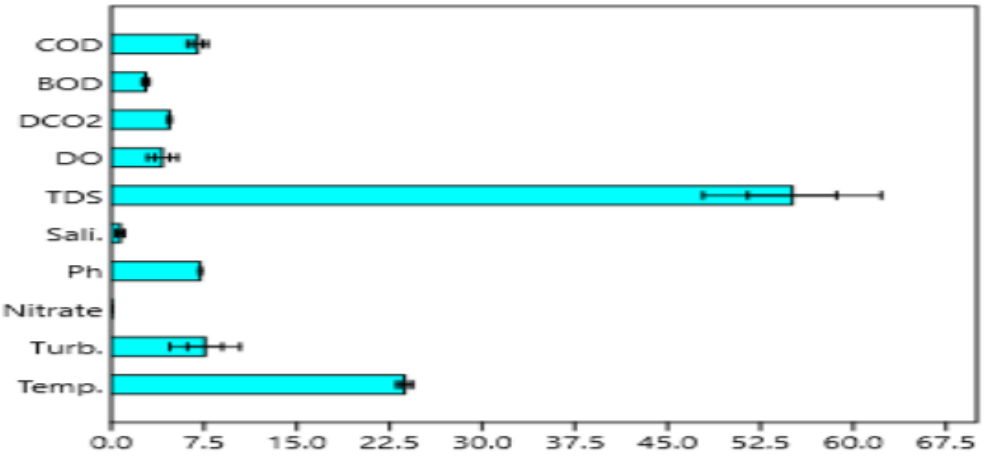

Figure 4. Box plot showing the levels of physico- chemical parameters.

The heavy metal concentrations (Lead, Arsenic, Cadmium, Iron, and Mercury) at four distinct stations (CS1: Vettukadavu Bridge, CS2: Pariyaram, Meloor, CS3: Kombanpara Check dam, CS4: Kallur, Thekkumuri Pulikkakadavu Bridge) along chalakudy river in India is given. The levels recorded in micrograms per liter (µg/L), are compared against the permissible limits for drinking water as defined by the Bureau of Indian Standards (BIS) IS 10500:2012. This station generally exhibits the lowest concentrations of all heavy metals compared to the other stations, suggesting it might be the least impacted by pollution within the sampled stretch. Lead (Pb): Lead levels

are consistently low, averaging around 3.45 µg/L, and pose no immediate concern. Arsenic (As): Arsenic levels are also the lowest at this station, averaging around 0.08 µg/L, indicating minimal arsenic contamination at this point. Cadmium (Cd): Cadmium levels are relatively low, averaging around 2.05 µg/L, but still present. This suggests some baseline cadmium presence in the water, possibly due to natural sources or upstream influences. Iron (Fe): Iron levels are the lowest here, averaging around 178 µg/L. While not posing a health risk according to BIS standards, even these levels might contribute to some aesthetic water quality issues. Mercury (Hg): Mercury is consistently below the detection limit (BDL), indicating no mercury contamination detected at this station. Overall: A slight increase in the levels of most heavy metals is observed at this station compared to CS1, indicating some input of pollutants between these two points. Lead (Pb): Lead levels have increased slightly, averaging around 3.98 µg/L, but remain well within the permissible limit. Arsenic (As): Arsenic levels also show a small increase, averaging around 0.12 µg/L, but are still very low. Cadmium (Cd): Cadmium levels continue to rise, averaging around 2.12 µg/L. This trend is a cause for concern, as we see the levels steadily increasing downstream. Iron (Fe): Iron levels also increase, averaging around 195 µg/L, further suggesting some addition of iron-containing substances to the water. Mercury (Hg): Mercury remains BDL. Overall: A more significant jump in the concentrations of several heavy metals is evident at this station, indicating a more substantial pollution source or a cumulative effect of multiple smaller sources. Lead (Pb): Lead levels show a noticeable increase, averaging around 4.67 µg/L, though still below the limit. Arsenic (As): Arsenic levels also increase, averaging around 0.17 µg/L. Cadmium (Cd): Cadmium levels continue their upward trend, averaging around 2.47 µg/L, getting increasingly closer to the permissible limit. This is a major concern. Iron (Fe): Iron levels rise significantly, averaging around 210 µg/L. Mercury (Hg): Mercury remains BDL. Overall: This station consistently shows the highest concentrations of most heavy metals, indicating the cumulative impact of upstream pollution sources. Lead (Pb): Lead levels peak at this station, averaging around 4.85 µg/L, but still within the limit. Arsenic (As): Arsenic levels are also the highest here, averaging around 0.18 µg/L. Cadmium (Cd): Cadmium reaches its highest level at this station, averaging around 2.71 µg/L, dangerously close to the 3 µg/L limit. Iron (Fe): Iron levels are the highest here, averaging around 225 µg/L. Mercury (Hg): Mercury remains BDL (Figure 4 & 5).

Table 4. Levels of heavy metals in water samples.

Heavy metal level in µg/ L (All values are in Mean ± SD form)						
Station Name	**Station Code**	**Lead (Pb)**	**Arsenic (As)**	**Cadmium (Cd)**	**Iron (Fe)**	**Mercury (Hg)**
Vettukadavu Bridge	CS1	3.45±0.12	0.08±0.01	2.03±0.02	178.21±2.01	BDL
Pariyaram,Meloor	CS2	3.93±0.31	0.12±0.01	2.12±0.02	195.43±2.17	BDL
Kombanpara Check dam	CS3	4.76±0.21	0.16±0.02	2.45±0.56	205.31±1.44	BDL
Kallur,Thekkumuri Pulikkakadavu Bridge	CS4	4.88±0.42	0.19±0.03	2.61±0.55	222.32±2.23	BDL
Permissible limit, BIS 2012		10	10	3	3	1

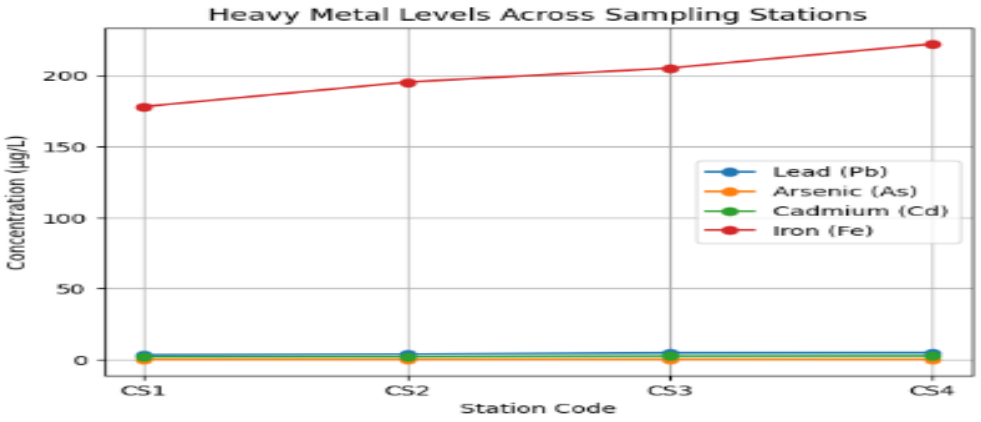

Figure 5. Line diagram showing Heavy metal levels.

Table 5. Summary of Highest Threat (Approaching or Near Limit).

Station Name	Station Code	Metal	Average Level (µg/L)	Permissible Limit (µg/L)	Threat Level
Vettukadavu Bridge	CS1	Cadmium	2.03 ± 0.02	3	Potential for future concern
Pariyaram, Meloor	CS2	Cadmium	2.12 ± 0.02	3	Increasing trend, warrants monitoring
Kombanpara Check Dam	CS3	Cadmium	2.45 ± 0.56	3	High concern, approaching the limit
Kallur, Thekkumuri Pulikkakadavu Bridge	CS4	Cadmium	2.61 ± 0.55	3	Highest threat, dangerously close to limit

CONCLUSION

The study analyzed the water quality parameters and heavy metal concentrations in water from different stations in Chalakudy river. The results showed that the water quality is generally satisfactory, with most heavy metal concentrations within the permissible limits set by the Bureau of Indian Standards (2012). Water samples from four distinct stations (CS1, CS2, CS3, and CS4) were analysed for heavy metal levels. The findings indicate variability in the concentrations of lead (Pb), arsenic (As), cadmium (Cd), iron (Fe), and mercury (Hg) among the stations. Station CS4 exhibited the highest concentrations of Pb, As, Cd, and Fe, with observed values of 4.79-4.88 µg/L for Pb, 0.17-0.19 µg/L for As, 2.61-2.77 µg/L for Cd, and 222-228 µg/L for Fe. The lowest concentrations were observed at station CS1. Mercury (Hg) levels were below the detection limit (BDL) at all stations, suggesting satisfactory water quality regarding Hg contamination. The findings indicate that the concentrations of Pb, As, Cd, and Fe comply with the permissible limits established by the Bureau of Indian Standards (BIS) in 2012. In conclusion, with respect to the provided data and the BIS 2012 drinking water standards, Cadmium is the metal posing the most significant and increasing threat as you move downstream, with Station CS4 (Kallur, Thekkumuri Pulikkakadavu Bridge) being the location where this threat is most pronounced. While other metals show increasing trends, their levels are currently further below their respective permissible limits. Therefore, monitoring and controlling Cadmium levels in this water body should be a priority.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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