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Seasonal Variations of Iron levels in the Meenachil river, Kottayam, Kerala, South India.

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KEYWORDS

Iron, Meenachil , monsoon, pre monsoon , post monsoon.

ABSTRACT:

Water with high iron content leads to discoloration of garments and sanitary items and gives a bitter astringent flavour. Issues with taste and smell can result from filamentous organisms that feed on iron compounds. Iron in little quantities is necessary for nourishment, but overdose may cause severe health issues. The Meenachil River, alternatively referred to as Kavanar or Valanjar, is a watercourse coursing through Kerala, India. Renowned for its perilous characteristics, including sudden floods, powerful undercurrents, and the transport of timber and debris from the mountains, it poses significant challenges to navigation. Flowing through the core of Kerala's Kottayam district, this river spans approximately 78 kilometers and originates in the Western Ghats, serving as a vital geographical feature in the southern Indian state.Water samples from 15 locations along the Meenachil River in Kottayam, Kerala, were taken over three seasons: pre-monsoon, monsoon, and post-monsoon, to monitor the level of iron. Many individuals use water from the Meenachil river for drinking and agricultural activities. The greatest iron content of 1056.15 µg/L was recorded at station MS 15 (Illikkal) in the downstream layer during the monsoon season. Station. MS 2 (Adivarum) reported the lowest concentration of iron at 11.63 µg/L during the pre-monsoon season. Iron levels exhibit a seasonal fluctuation at all locations, peaking during the monsoon. Iron levels are often higher at downstream sites than at upstream and middle stream stations. Water quality management is crucial in the research region. It is imperative to formulate proficient management approaches to alleviate iron contamination and uphold the ecological balance of river ecosystems.

1. Introduction

Iron (Fe) is the second most abundant metallic element in the earth's crust. It can be present in water in either ferrous or ferric form, either suspended or dissolved. Under reducing circumstances, iron is present in the ferrous form. When exposed to oxygen, the ferrous ion undergoes oxidation and transforms into the ferric form. Iron gives water a metallic taste and causes yellowish-

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red to brown stains on clothes, dishes, and plumbing fixtures. Moreover, it can block pumps, sprinklers, and other mechanical devices [1]. The Bureau of Indian Standards (BIS) recommends iron levels in drinking water to be below 0.3 mg/L and considers values up to 1.0 mg/L as acceptable. Water quality is affected if it exceeds a concentration of 1.0 mg/L, resulting in alterations in taste and visual characteristics. This concentration also promotes the growth of iron bacteria. Moreover, these bacteria are accountable for producing unpleasant smell and taste. Therefore, it is customary to routinely evaluate the iron content in drinking water. Iron assessment is considered a vital component in regular water quality assessments [3,4,5,6].

The tropical fluvial ecosystem exhibits distinct characteristics due to its climatic conditions, which include considerable seasonal rainfall, prolonged periods of drought, and high ambient temperatures. These conditions contribute to strong geochemical fractionation, elemental partitioning, and quantitative transit [7]. The hydro-geochemical analysis of this environment can be directly associated with the impact on human health, which contributes to the advancement of a recently established field of Earth System Science called Medical Geology [8]. An extensive and reliable collection of investigations spanning the geosphere and biosphere is crucial and should be regarded as a fundamental element of environmental knowledge [9, 10].

Iron is frequently found in natural water in both ferric and ferrous forms. Oxidation, reduction, or bacterial development during storage can alter the structure of Iron. In most natural water bodies, the ferric form is usually the most common. Iron in water can be found in three forms: true solution, colloidal state, or as big suspended particles. Water containing high quantities of iron causes staining on clothes and bathroom fixtures, and imparts a strong and astringent taste. Filamentous organisms that consume iron compounds can cause taste and odour problems. Iron is an essential component for nutrition, as demonstrated by scientific research [15,16,17].

The Meenachil river traverses the Kottayam district in the state of Kerala, India.The river spans 78 kilometres and passes through Poonjar, Teekoy, Erattupetta, Pala, Ettumanoor, and Kottayam.Many residents living along the riverbank use the water primarily for drinking, household, and agricultural activities [18].

2. Objectives

In recent years, there has been increasing focus on iron (Fe) levels in river water and their impact on human health, especially in regard to the standards established by the World Health Organisation (WHO) and the Indian Standards Institution (ISI) [19,11]. The current inquiry focuses on finding the factors that affect the amounts of iron (Fe) in the water of the Meenachil river. The local community mostly uses this river for drinking, residential, and agricultural purposes. This effort aims to provide practical techniques for regulating iron levels in various locations along the Meenachil River.

3.Material And Methods

3.1 Water Sampling

Water samples were gathered from the Meenachil river throughout three main seasons: pre-monsoon (February – May 2022), monsoon (June – September 2022), and post-monsoon
(October 2022 – January 2023). Figure-1 displays a comprehensive map of the Meenachil river indicating the locations where samples were collected. Table -1 presents a concise overview of sample sites, including the station name, station code, latitude, and longitude.

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The map of the sampling stations' locations on Google is provided in Figure 2.

Water samples were gathered in polyethylene containers with secure caps and were acidified on-site with HNO3 (5 ml/lit of water). This process will not impact the dissolved metal concentrations because of the minimal presence of particulate matter in the samples collected throughout various seasons. To prevent contamination, the samples were placed in polypropylene bags to avoid direct touch and maintained at 4°C for preservation until further chemical analysis [20,21].

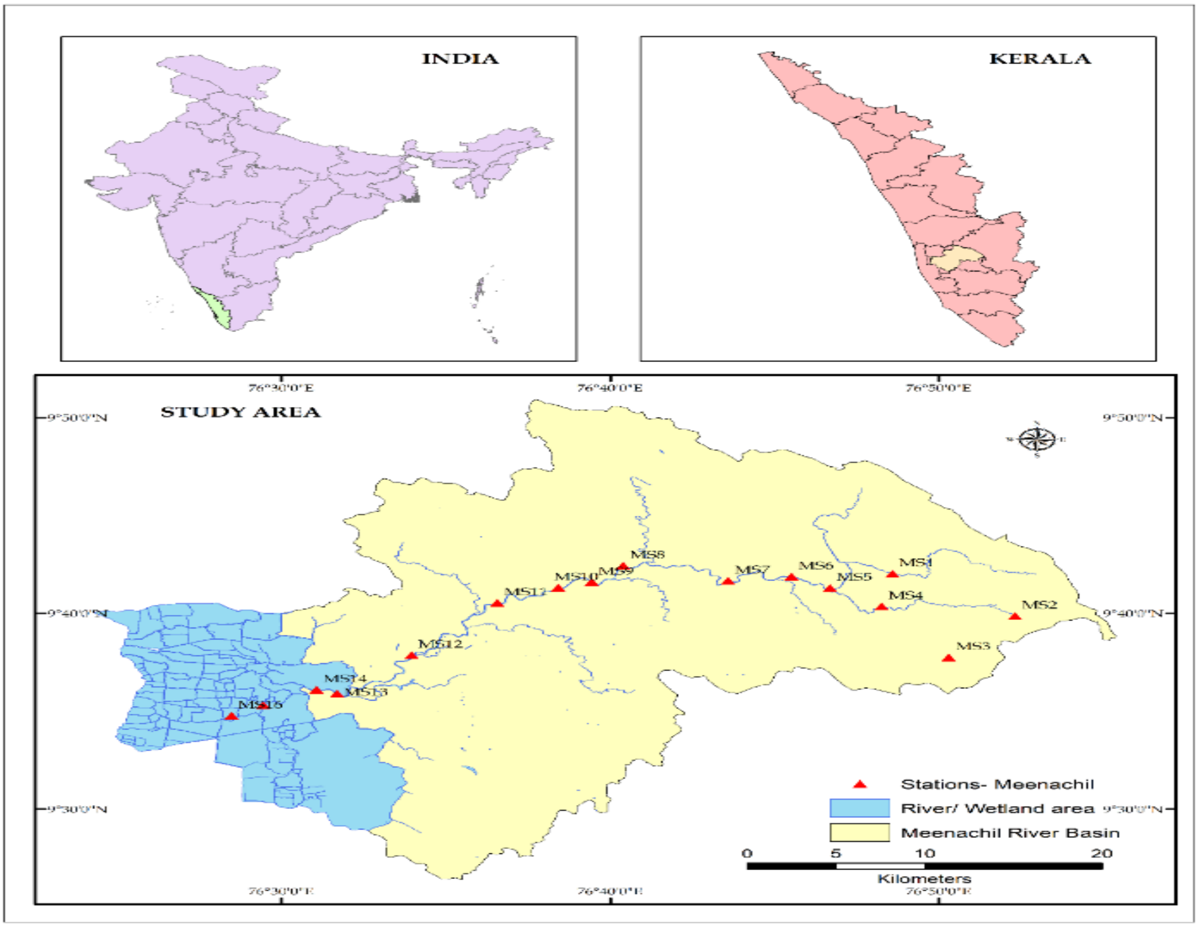
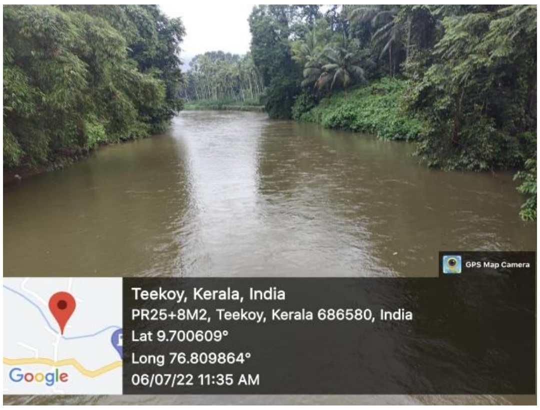


Figure: 1 Map of Study area

Table : 1 Sampling stations – Meenachil River

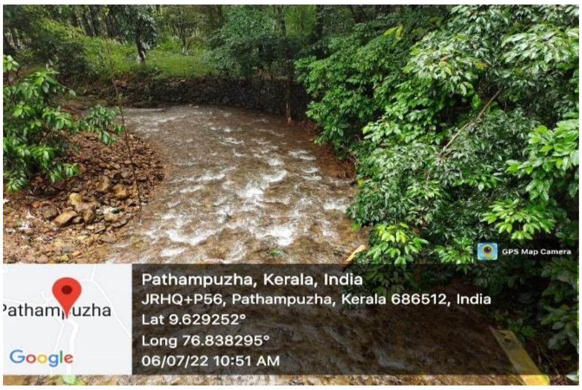
Station No & Code	Station Name		Location	
			Latitude(°N)	Longitude(°E)
Station 1 (MS 1)	Teekoy	Upstr	9.70044574	76.80981721
Station 2 (MS 2)	Adivaranum		9.6644° N	76.8720° E

Station 3 (MS 3)	Pathampuzha		9.62930039	76.83838426
Station 4 (MS 4)	Poonjar		9.6727	76.8043
Station 5 (MS 5)	Erattupetta		9.6883	76.7782
Station 6 (MS 6)	Panaykkapalam	Middle stream	9.69799098	76.75867725
Station 7 (MS 7)	Bharanaganam		9.69446806	76.72642686
Station 8 (MS 8)	Pala / Kadapatoor		9.70730511	76.67326924
Station 9 (MS 9)	Mutholy		9.69334756	76.657335
Station10 (MS 10)	Cherpunkkal		9.68867957	76.64045146
Station11 (MS 11)	Kidangoor		9.67573128	76.60944832
Station12(MS 12)	Poovathummoode /Ettumanoor	Down stream	9.63116532	76.56605529
Station 13 (MS 13)	Nagambadam / Kottayam		9.59846837	76.52823115
Station 14 (MS 14)	Chunkam		9.60174279	76.51775587
Station 15 (MS 15)	Illikkal		9.58851622	76.49071296



MS 1

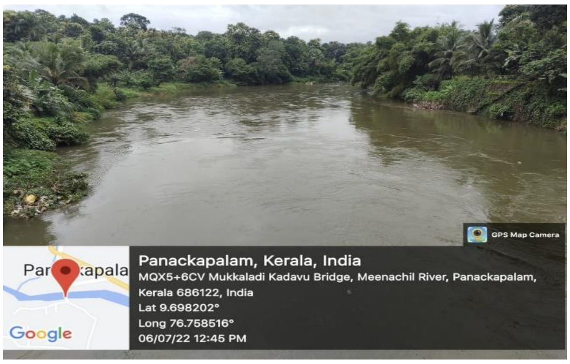
MS 2



MS 3

MS 4

MS 5



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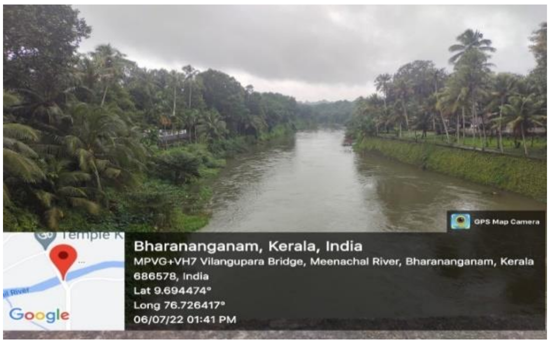

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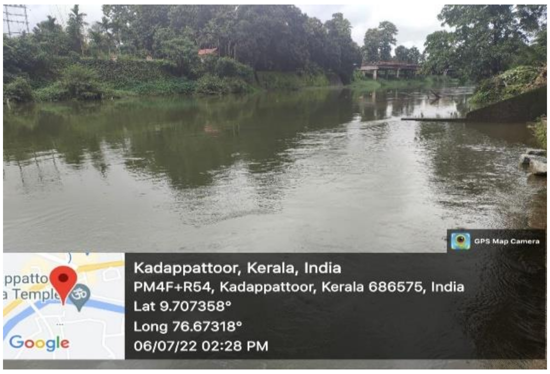
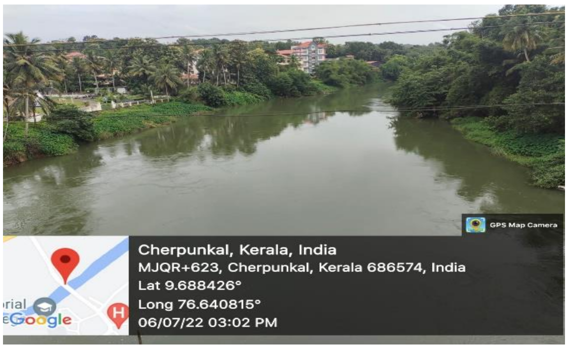


MS 8

MS 9



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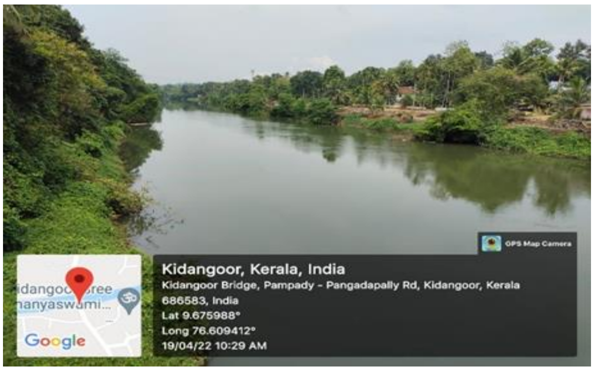

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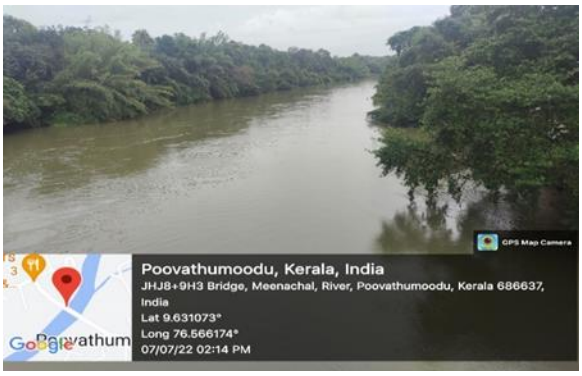

MS 12

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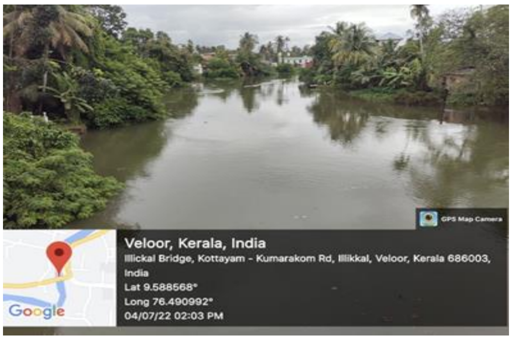
MS 13

MS 14



MS 15

MS 16

Figure : 2 Location map of sampling stations – Meenacil River

3.2 Sample analysis

Samples were preserved with supra pure nitric acid and stored at below room temperature before analysis. Inductively coupled plasma-mass spectrometry, ICP-MS, (iCAP Q, Thermo Fisher) was used for the determination of iron. Standardization done with the multielement standard (VHG labs). The concentration of element is 100 micrograms per milliliter in the standard.

Figure: 3 ICP – MS

4. OBSERVATION AND RESULTS

The determined values of Iron in water samples for three seasons are reported in Table 2. The season-wise variation of Iron concentration is graphical presented in Figure-4. The WHO and ICMR standard for iron concentration in water is 0.1mg/lit (100 µg/L) and permissible limit prescribed by USPH and ISI is 0.3mg/lit (300 µg/L) [11,19].The results are demonstrated by the minimum and maximum values, average values and statistical evaluations i.e. Standard Deviation (SD), Standard Error (SE), 95% Confidence Limit of the iron in water sources from the Menachil river.The level of iron was high in all the layers in monsoon and least in pre monsoon season. In the monsoon the levels of iron in upstream (84.33±11.37) , middle stream (220.89±13.57) and down stream

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(456.45±81.08). Middle stream and down stream indicates the higher value of iron and it indicates above the permissible limit.

5.DISCUSSION

Present study revealed that, a general tendency of increasing the Fe from upstream to down stream. When compared with the BIS specification for drinking water, the iron content during monsoon and post monsoon was above the permissible limit of 100 µg/L (1.0 mg/L), in middle stream and down stream . But in up streams in the seasons the iron level is with in the permissible limit.

The graph (Fig. 4) shows that the iron levels in the Meenachil river are highest in the monsoon season and lowest in the pre monsoon season, with the post monsoon season falling in between. The iron levels are also higher in the upstream, middle, and downstream layers of the river during the monsoon season, with the lowest levels being observed in the downstream section during the monsoon season. Highest concentrations of iron are reported during monsoon season and the lowest concentration is reported during pre monsoon season. The highest concentrations (1056.15 µg/L**)** of iron was reported from station MS 15, (Illikkal) of the down stream layer during the monsoon season.The least concentrations(11.63 µg/L) of iron was reported from station MS 2 (Adivarum) during the pre monsoon season.

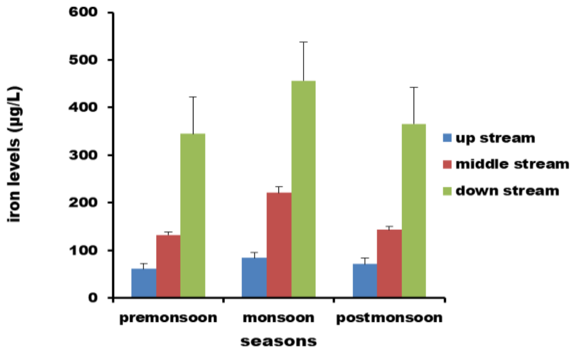

Figure - 4. Comparison of iron levels in different seasons in the Meenachil river, Kottayam

Table : 2 Iron levels (µg/l) in water samples of Meenachil river , Kottayam (Triplicate samples from 15 stations)

			Iron level in µg/l							
Station code	Layer	Pre monsoon			Monsoon			Post monsoon		
		Sample 1	sample 2	sample 3	Sample 1	sample 2	sample 3	Sample 1	sample 2	sample 3
MS1	Upstream	34.02	36.98	35.42	69.02	70.23	71.01	39.75	40.32	40.15
MS2		11.63	12.23	12.07	17.47	21.11	18.21	22.76	18.01	16.13
MS3		110.78	112.09	112.97	134.13	128.23	128.46	124.38	123.56	124.87
MS4		33.34	32.17	33.87	69.32	72.21	70.23	42.81	43.09	42.99

MS5		114.46	115.09	116.01	132.14	132.45	130.73	129.61	130.01	130.53
MS6	Middle stream	97.08	99.13	98.08	126.23	127.45	128.34	104.21	104.33	105.91
MS7		144.41	139.56	143.82	266.12	258.38	253.21	167.62	168.23	167.11
MS8		165.23	168.09	165.97	274.43	269.01	268.79	177.11	178.07	177.22
MS9		110.98	112.54	111.72	213.56	218.76	215.24	118.39	118.96	119.76
MS10		143.16	147.78	146.41	229.23	230.26	234.38	149.12	148.21	150.05
MS11		246.89	245.51	246.02	285.67	289.04	286.51	259.12	258.11	260.32
MS12	Down stream	421.65	419.04	420.39	320.56	326.53	327.09	453.02	453.98	452.93
MS13		177.09	177.11	178.91	341.34	348.23	349.08	193.23	196.97	199.23
MS14		158.12	159.02	157.09	380.98	379.57	375.98	172.22	181.56	178.38
MS15		879.21	880.06	881.95	1056.15	1045.76	1043.64	893.67	896.23	888.23

Layers	**sites**	**Iron levels (μg/L) in different seasons**					
		pre-monsoon		**monsoon**		**post monsoon**	
		Sites*	**Layers****	**Sites***	**Layers****	**Sites***	**Layers****
Upstream	MS1	35.47 ± 0.85	61.54±11.57	70.09±0.57	84.33±11.37	40.07±0.16	71.26±12.41
	MS2	11.97 ±0.18		18.93±1.11		18.96±1.97	
	MS3	111.94±0.64		130.27±1.92		124.27±0.38	
	MS4	33.12±0.50		70.58±0.85		42.96±0.08	
	MS5	115.18±0.45		131.77±0.52		130.05±0.27	
Middle stream	MS6	98.09±0.59	132.93±6.60	127.34±0.61	220.89±13.57	104.81±0.54	143.62±7.43
	MS7	142.59±1.52		259.23±3.75		167.65±0.32	
	MS8	166.43±0.85		270.74±1.84		177.46±0.30	
	MS9	111.74±0.45		215.85±1.53		119.03±0.39	
	MS10	145.78±1.36		231.29±1.57		149.12±0.53	

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	MS11	420.36±0.75		324.72±2.08		453.31±0.33	
	MS12	177.70±0.60		346.21±2.45		196.47±1.74	
Down stream	MS13	158.07±0.55	345.29±77.49	378.54±1.29	456.45±81.08	177.38±2.74	365.85±77.01
	MS14	880.40±0.80		1048.51±3.86		892.71±2.35	
	MS15	89.92±0.35		184.28±2.10		109.38±0.45	

Table 3: Iron levels in the water samples of Meenachil river, Kottayam (With mean and SD value of 3 layers)

*Mean ±S.E. of three observations, ** mean ±S.E. of of four sites, significance at 0.001 level on multiple comparisonbetween the upstream, middle stream, and downstream layers in the pre-monsoon, monsoon and post monsoon seasons.

The graph (Figure 5) shows that the iron levels in the Meenachil river are highest in the monsoon season and lowest in the pre monsoon season, with the post monsoon season falling in between. This is true for all three water layers (upstream, middle stream, and downstream). The graph also shows that the iron levels in all three water layers vary seasonally, with the highest levels being observed in the monsoon season and the lowest levels being observed in the pre monsoon season. The level of iron is high in the down stream layer and least in the upstream layer .

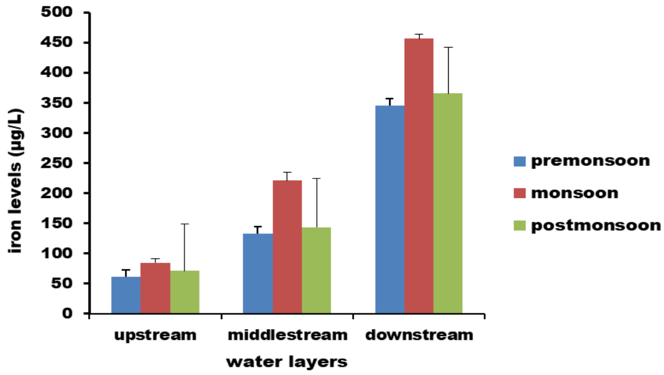

Figure . 5 Comparison of iron levels in different water layers in different seasons in the Meenachil river, Kottayam

The monsoon seasons are characterized by intense rainfall, leading to increased erosion of soil and sediment transport into rivers. This erosion carries iron-rich particles from terrestrial sources, contributing to elevated iron levels in river water [22]. Monsoon rains stimulate the decomposition of organic matter in soils and water bodies. This process releases iron bound within organic compounds, further augmenting iron concentrations in rivers [23]. Fluctuations in water levels and oxygen availability during monsoon seasons create conducive conditions for redox reactions involving iron minerals. These reactions can lead to the dissolution of iron oxides and subsequent release of soluble iron into the water column [24]. Human activities such as mining, industrial discharge, and agricultural runoff can significantly contribute to iron pollution in rivers, especially during the monsoon seasons when runoff volumes are high [25].

Studies of Indu *et al* 2010 [26] also indicates high during levels of iron in Meenachil river during monsoon . Since there is no major industrial activity in the study area, the major reason for the increase in Fe content might be due to the terrestrial runoff from the rocks present in the area. Charnockite groups of rocks which are rich in Fe content are the prevalent rock type in the basin. They might have undergone weathering and erosion process during monsoon period [27]. Another reason for the increase in Fe content might be due to the disposal of domestic wastes which is supported by the studies conducted by Neal et al.[28]. and Bordalo et al.[29]. in which they found that domestic effluents act as an important source of trace metals. Excess of iron concentration in water causes staining of cloths and utensils. The water may also have a metallic taste and an offensive odor [30].

The current study investigated the seasonal variation of iron levels in the Meenachil river water across three distinct seasons, pre-monsoon, monsoon, and post-monsoon. Findings revealed significant seasonal fluctuations in iron concentrations, with the highest levels observed during the monsoon season and post monsoon and the lowest during the pre monsoon season. These seasonal trends are consistent with previous studies conducted in other tropical regions[31].

During the monsoon season and post monsoon the high rainfall and maximum runoff contribute to reduced erosion and weathering of iron-rich minerals in the catchment area, leading to higher iron concentrations in river water. Additionally, the absence of excessive surface runoff during this period limits the transport of iron-rich sediments into the river system[32].The onset of the monsoon season brings about a dramatic shift in iron levels. The increased rainfall intensity intensifies erosion and weathering processes, releasing iron from soil and rock formations into the river system [33].

The seasonal variations observed in iron levels have implications for various aspects of the river ecosystem. High iron concentrations during the pre monsoon and post monsoon season can potentially affect aquatic organisms, influencing their physiology and reproductive cycles . Additionally, elevated iron levels may impact water quality parameters, such as dissolved oxygen levels and nutrient availability, which can indirectly affect aquatic biodiversity and ecosystem functions [34].

Understanding the seasonal patterns of iron levels in Indian rivers is crucial for developing effective management strategies to mitigate the potential impacts of iron pollution on aquatic ecosystems. Monitoring iron concentrations throughout the year and implementing measures to reduce erosion and sediment runoff during the monsoon season can help maintain water quality and protect aquatic biodiversity. Additionally, promoting sustainable land-use practices in catchment areas can reduce the influx of iron-rich sediments into rivers, further contributing to improved water quality.

Kerala, a state in southern India, is heavily reliant on the annual monsoon for its water resources. However, the monsoon patterns in Kerala have been changing in recent decades, leading to increased rainfall variability and extreme events . These changes are attributed to a combination of factors, including global warming, urbanization, and deforestation [30].

One of the most significant changes in the monsoon patterns in Kerala is the increased variability of rainfall. This means that there are more frequent and intense periods of both heavy rainfall and dry spells [31].This variability has had a number of negative impacts on Kerala, including increased flooding, landslides, and water scarcity .In addition to the increased variability of rainfall, Kerala has also been experiencing more extreme rainfall events in recent decades. These events are characterized by very heavy rainfall over a short period of time, which can lead to widespread flooding and landslides [30]. The 2018 Kerala floods, which killed over 400 people and displaced over a million more, were an example of an extreme rainfall event [35].

The changes in the monsoon patterns in Kerala have also had a significant impact on agriculture. The increased variability of rainfall has made it more difficult for farmers to plan their crops, and the extreme rainfall events have led to crop losses and decreased yields [36].

6.CONCLUSIONS

The present study has demonstrated the significant seasonal variability of iron levels in the Meenachil river water, with the highest concentrations observed during the monsoon and post monsoon season and the lowest during the pre monsoon season. These fluctuations are driven by the influence of rainfall and its associated factors on iron mobilization and transport in the river system. High concentrations of iron are reported to be injurious to human health and causes a number of diseases related to stomach. Iron in the form of ferrous is oxidized to ferric imparting a turbidity of water. Understanding these seasonal patterns is crucial for assessing the potential impacts of iron on aquatic ecosystems and developing effective management strategies to maintain water quality and protect aquatic biodiversity.

High concentrations of iron are reported to be injurious to human health and causes a number ofdiseases related to stomach. Iron in the form of ferrous is oxidized to ferric imparting a turbidity of water [37].

The elevated levels of iron in rivers during monsoon seasons pose several challenges, including impacts on aquatic life, water treatment processes, and human health. Further research is needed to comprehensively understand the dynamics of iron cycling in river ecosystems during monsoon periods. This includes investigating the role of microbial activity, sediment transport mechanisms, and the influence of climate change on iron mobilization. Additionally, effective management strategies must be developed to mitigate iron pollution and safeguard the ecological integrity of river systems.

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STATEMENT OF CONFLICT OF INTEREST

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