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A Heavy Metal Contamination in Cauvery River Water – A Case Study of Kumbakonam, Thanjavur District, Tamil Nadu

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Abstract

Importance of water in our everyday lives cannot be overstated. Many heavy metals are present in natural water, but only at very low concentrations. Certain metals are essential to both human and animal health, but too much of these may be dangerous. The current study aimed to determine heavy metals such as Hg, Cd, As, Pb, Cr, Ni, Se, Cu, Zn, and Fe using Atomic Absorption Spectrophotometer. The study was conducted on river Cauvery at the Kumbakonam regions of Tamil Nadu during two seasons (monsoon and post-monsoon). The results highlighted that among studied metals chromium and lead were found to be present during both seasons across all studied areas. It was observed that cadmium, arsenic, chromium, nickel, selenium, cadmium, arsenic and zinc were crossing permissible limits (WHO, 2017) in both post-monsoon and the monsoon seasons. However, mercury, copper, zinc, and iron had concentrations within the limits of WHO in all studied areas during both seasons. The sampling sites were selected based on their importance like dyeing industries, tanneries due to the release of effluents from power plants, steel factories, and cement factories, etc. Here various industries were responsible for the release of wastewater into the river. Heavy metal concentrations in the results revealed that the Cauvery river water became contaminated due to heavy concentrations of lead, cadmium, arsenic, chromium, nickel, and selenium. Awareness has to be promoted among those who work in industries, those who clean up after those companies, those who work for municipalities, and those who live in and around the areas being studied.

Keywords: Heavy metals, Contamination, Cauvery River, Industrial effluents, anthropogenic activities

INTRODUCTION

Water is an essential component of our day-today activities. But due to population growth water resources have been polluted (Sonone *et al.*, 2020). An enormous amount of heavy metals are being discharged by anthropogenic activities (Nduka and Orisakwe, 2011) and at the same time natural processes like weathering, leaching from garbage also contributes to metal contamination in the aquatic enironment (Grigoratos *et al.*, 2014 and Martin *et al.*, 2015). Therefore, Monitoring heavy metal concentration is very important because of their toxicity and their bioaccumulation in living organisms (Miller *et al.*, 2002).Due to the toxicity, non-degradation, and bioaccumulation, of the heavy metals render water unsuitable for drinking and cause severe risk to human beings (Chowdhury *et al.*, 2016). Generally, metals are categorized as biologically essential and nonessential. Elements like Cu, Cr, Fe, Mn, and Zn are essential for animals and human beings because they play an important role in different metabolic functions, enzymatic activities, sites for receptors, hormonal function, and protein transport at specific concentrations (Antoine *et al*., 2012). Non essential heavy metals like Cd, Hg, Pb, and Sn have no known essential role in living organisms and they exhibit extreme toxicity even at very low exposure levels and have been regarded as the main threats to all forms of life especially human health (Jarup, 2003).Essential and nonessential elements are regularly added to our food chain through excessive use of agrochemicals, municipal wastewater, industrial effluents, etc., (Nouri *et al*., 2011). Heavy metal contamination is measured using fish and shellfish. Because metals biomagnify in biota and are hard to break down, it is vital to analyse the metal concentration in fish and fish meat to ensure food safety and safeguard consumers (Malhotra *et al*., 2020). As a result of global warming, floods and droughts are happening more often, which has sped up the process of urbanisation. Heavy metals have been found in the water further down the Cauvery River, as shown by tests on the water, plankton, and fish sediment (Begum *et al*., 2009). Carbonate hardness was found to be very high in the water samples. Our infrastructure is also getting worse, which makes it more likely that people will cause accidents. Susheela *et al.* (2014) said about how important it is to protect a city's infrastructure for sustainability from both natural and man-made dangers.

Human activities such as industrial and municipal effluents, land fill leaching, non point source such as run-off and atmospheric deposition have increased the flux of heavy metals in rivers (Klavins *et al*., 2000). Heavy metal gain access into aquatic bodies and soil through the natural geochemical processes and the discharge of treated, untreated wastewater into river water. The metal toxicity, mobility and bioavailability depend on speciation pattern rather than the total metal concentration.

Rivers play a major role in transporting industrial and municipal wastewater and runoff from agricultural and mining areas (Singh *et al*., 2004). Contamination of heavy metals may have horrifying effects on the ecosystem and on the diversity of aquatic organisms (Farombi *et al.*, 2007). Chemical leaching of bedrocks, water drainage basins and runoff from river banks are the primary natural sources of heavy metals accumulation. Compare to the natural sources of heavy metal pollution, anthropogenic discharges such as urban discharges and industrial waste water, combustion of fossil fuels, mining and smelting operations, processing and manufacturing industries, waste disposal including dumping, etc., are considered as major polluting sources (Klavins et *al*., 2000 and Upadhyay *et al*., 2006). Sediments are mixture of several components of mineral species as well as organic debris, represent as an ultimate sink for heavy metals discharged into environment (Abbas *et al*., 2009). Since Cauvery river is one of the important source of water for irrigation as well as drinking. About more million liters per day is being supplied daily to the public in the kumbakonam. So it was in this backdrop the present study was aimed to investigate the water quality status of the Cauvery river concerning its heavy metal concentrations in two seasons at study areas kumbakonam, Thanjavur districts. The research work was carried during the post-monsoon season (December) in 2022 and the monsoon season (August) in 2023.

MATERIAL AND METHODS

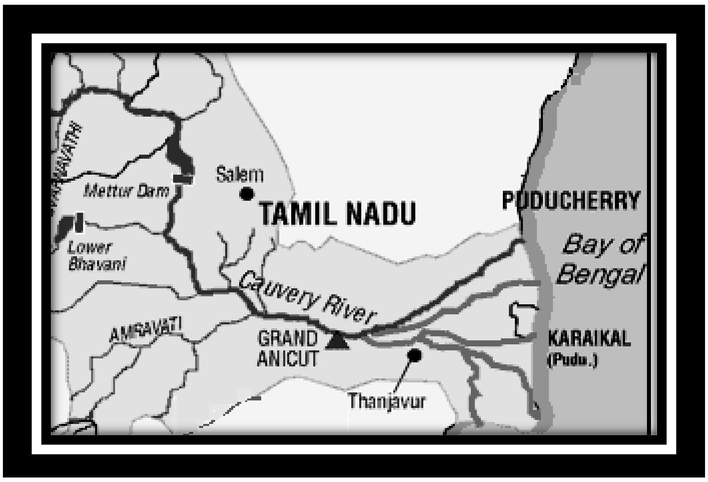
Sampling Sites

Present study was conducted on a stretch of the Cauvery river, which passes through Karnataka and TamilNadu. It flows about 800 kilometers before reaching the Bay of Bengal. It is the third-largest river in Tamil Nadu. (Figure.1) The primary use of this river is for household consumption, irrigation, and electricity generation. A total of three sampling sites were selected Thanjavur districts. The site I was Kabisthalam **(**10°56'29.8"N and 79°15'19.7"E). Site 2 was Ayyampettai (10°54'53.3"N and 79°11'11.5"E).Site 3 was Kumbakonam (10°58'11.2"N and 79°22'57.2"E). Here surrounding the areas spinning and weaving mills, paper industries, dyeing industries, tanneries, printing industries, welding works, painting works for vehicles, handloom and power loom industries are located. Since these sampling sites received a lot of agriculture and domestic sewage apart from industrial effluents. Hence these sites were selected for the assessment of the concentration heavy metal.

Sample Collection and Preservation

The water samples were collected during postmonsoon (December 2022) and monsoon (August 2023). At a time 3 liters of water samples were collected and stored in airtight containers followed by preservation using an ice-box, and transferred to the laboratory. Heavy metal analysis Water samples were carefully handled to avoid contamination. Beakers and other glassware were thoroughly cleaned using distilled water. A 100 ml water sample was taken in a beaker and digested using 5 ml of concentrated HNO_3. Then it was filtered using Whattman filter paper and make volume up to 100 ml in a volumetric flask by adding double-distilled water. Heavy metal standard solutions were prepared using double distilled water for different concentrations (nice traceable) to 0.001, 0.002, 0.003, 0.004, 0.005 and 0.01 mg/l from 1000 ppm solution. Then the heavy metal concentrations of the collected water samples were determined by atomic absorption spectrophotometer (AAS). Cadmium, chromium, copper, iron, lead, nickel, selenium, and zinc were detected on flame mode using acetylene gas, and arsenic, mercury were detected by using vapour generation assembly on AAS as per IS 3025: Reaff 2014 testing protocols (BIS, 1994).

Figure 1: Map of Cauvery River basin in Tamilnadu



Statistical Analysis

The data was analyzed statistically. The mean of the heavy metal concentrations in water samples were calculated.

RESULTS AND DISCUSSION

Heavy metal contents in water samples the mean concentration of different metals were shown in Table 1. The results revealed that the mean concentrations of heavy metals in water samples collected from various sampling sites during the post monsoon season (2022) (mg/l)showed the following order; Zn (0.86) > Cu (0.66) > Fe (0.26) > Cr (0.06) > Ni (0.06) >As(0.04) >Pb(0.036)> Se (0.033) > Cd (0.004) > Hg (0.003).Table 2 showed the concentrations of heavy metals in water samples collected from various sampling sites during the monsoon season (2023). The results revealed that the mean concentrations of heavy metals are in the following order: Zn (1.27) > Fe (0.036) > Cr (0.03) >Pb (0.027) > As (0.015) > Se (0.0086) > Cd (0.0053) > Cu (0.003) > Ni, Hg (BDL) (mg/l). The mean results showed that the metal order had remained almost same during both the seasons, however, concentrations of few metals showing slight oscillation.

Table 1. Heavy metal concentration (mg/l) in water samples at different sampling sites in the post-monsoon season (2022).

Sites	Hg	Cd	As	Pb	Cr	Ni	Se	Cu	Zn	Fe
S1	0.002	0.01	0.02	0.03	0.04	0.06	0.04	0.5	0.7	0.4
S2	0.003	BDL	0.04	0.04	0.04	0.04	0.02	0.5	0.4	0.1
S3	0.004	0.004	0.06	0.04	0.1	0.08	0.04	1	1.5	0.3
WHO Limits	0.001	0.005	0.01	0.05	0.05	0.1	0.02	1	5	0.3
Mean	0.003	0.004	0.04	0.036	0.06	0.06	0.033	0.66	0.86	0.26

Table 2. Heavy metal concentration (mg/l) in water samples at different sampling sites in the monsoon season (2023)

Sites	Hg	Cd	As	Pb	Cr	Ni	Se	Cu	Zn	Fe
S1	BDL	0.004	0.018	0.024	0.03	BDL	0.006	0.002	0.98	0.01
S2	BDL	0.005	0.012	0.026	0.02	BDL	0.008	0.002	1.47	0.02
S3	BDL	0.007	0.016	0.031	0.04	BDL	0.012	0.005	1.38	0.08
WHO Limits	0.001	0.005	0.01	0.05	0.05	0.1	0.02	1	5	0.3
Mean	0	0.0053	0.015	0.027	0.03	0	0.0086	0.003	1.27	0.036

Zinc

The results revealed that the zinc content was highest compared to other metals across the studied sites. The presences of zinc in the studied areas were in the following order: S3 (1.5) > S1 (0.7)>S2 (0.4) in post-monsoon season and in the following order S2 (1.47) > S3 (1.38) > S1 (0.98) during monsoon season (Fig. 2 & 4). This high concentrations might be due to artificial pathways like steel production, coal-fired power stations, burning of waste materials, and even fertilizers also. The Zn content from river Cauvery was also observed by Mahadev and Siamak (2010) as 0.148 mg/l and Raju *et al.*, (2013) as 4.3 to 23.4μg/l and 1.25 to 9.42 μg/l in pre-monsoon and post-monsoon season respectively. Both their results showed concentration lower than our findings. Hussain *et al.*, (2017) also reported very low concentrations of zinc ranging from 0.2 - 94.23 μg/l in the Godavari river basin. Zinc content across the studied area was lower than the allowable limit of 5 mg/l (WHO, 2017). When it comes to zinc's effects, aquatic animal species span a wide toxicity tolerance range. Alterations occur as a result of familiarity with one's surroundings and age, respectively. Zinc depletion decreases a population's resilience over time. For this reason, there is a broad range of doses that are deemed lethal. Concerns concerning zinc's toxic effects on the body are not well understood. As it damages the tissues in the gills, which the fish need to breathe, at lethal concentrations, it is guaranteed to kill fish. Exposure to potentially lethal concentrations of this substance may cause stress that ultimately leads to death (And and Wood, 2004). This nonspecific action of zinc implies that its effects will vary with both its concentration and the stage of life at which it is found. This is due to the fact that zinc has a redox potential and hence interacts with other elements in its surroundings.

Copper

Figure 2 and 3 showed that the copper concentrations ranged among sites in the following manner: S3 (1.0) > S2, S1 (0.5) and S3 (0.005) > S2, S1 (0.002) in the postmonsoon and monsoon season respectively. Its concentration across the studied sites was well below the permissible limits of 1.0 mg/l (WHO, 2017). A concentration of 0.04 mg/l was recorded by Islam et al. (2014) in the Shitlakhya river of Bangladesh. Mahadev and Siamak (2010) reported 0.057 mg/l of Cu from river Cauvery, which was lower than our mean value of post-monsoon season but equal the mean value of monsoon season. Overconsumption of copper may have negative consequences, hence a daily maximum of 10 mg has been set as a guideline. The danger of copper poisoning is higher in infants and newborns because their biliary excretion systems are not fully matured and because they absorb more copper via their intestinal walls (Copper IOM, 2001).

Chromium

The Chromium concentrations in the studied areas during the post-monsoon season (Fig. 2) were highest at site S3 (0.1) followed by S2 and S1 (0.04). chromium also recorded higher concentration than other metals during post-monsoon season. During monsoon season the results revealed that S3 (0.04) > S1 (0.03) > S1 (0.02) in monsoon season (Fig. 3). Similar results were also reported by Raju *et al.*, (2013) as Cr content was higher in the post-monsoon (0.7 μg/l) season than pre-monsoon season (0.5μg/l). Ali *et al.*, (2016) reported 69.56μg/l of Cr in summer and 86.93μg/l in the winter season in Karnaphuli river in Bangladesh. It was very higher than our findings. However, results revealed that the chromium content at S1, S2, and S3 was crossing the WHO permissible limit during post-monsoon season, and in the monsoon season its concentration was well within the limit (0.05

mg/l) set by WHO, 2017. Low concentration during monsoon season might be due to its dilution by water.

Iron

Iron occurs naturally in water, soil, sediments, and in the sedimentary rocks. It was also observed across the study sites. The presence of Fe in the studied areas was in the following order: S1 (0.4) > S3 (0.3) > S2 (0.1) in postmonsoon season (Fig. 2). Figure 3 showed that iron ranged as follows; S3 (0.08) >S2 (0.02) > S1 (0.01) in monsoon season. Very high levels of Fe (8.154 mg/l) content was recorded by Mahadev and Siamak (2010) while Raju *et al.*, (2013) reported that iron content ranged from 13.5 - 207.9µg/l in pre-monsoon and 71.7 - 486.0 µg/l in the post-monsoon season.Thus complementing our results. Hussain *et al.*, (2017) reported that the amount of iron ranges from 1 – 240 µg/l in the Godavari river. Overall the Iron content across the study sites was found to be lower than the allowable limit of 0.3 mg/l (WHO, 2017). Hence it cannot be responsible for any health hazards. As a consequence of this, ferric
precipitates are the primary kind of iron that should be taken into consideration when developing standards for the protection of aquatic life (Cadmus *et al*., 2018).

Lead

Lead poisoning, for example, may cause high blood pressure and anaemia in humans and animals, and it can impair the brains of foetuses, young children, and pregnant women, among other vulnerable populations. Lead is the also presents in good concentrations next to chromium across the studied area in both seasons, therefore, this river is heavily contaminated by lead. It was very high at S3 followed by S2 and S1 (Fig. 3). Lead also showed considerable increase during post-monsoon season with values ranging from S3 (0.04) > S2 (0.04) >S1 (0.03) (Fig. 2). Figure 3 depicted that its concentration was higher than other metals, it progressively increased from S3 (0.031) > S2 (0.026) > S1 (0.024) in monsoon season. However, the content of Pb across study sites was higher than the allowable limit (0.01 mg/l) set by WHO (2017). Bhuyan *et al*., (2019) found concentration of lead as 0.11 mg/l. While, Ahmed *et al.*, (2012) as 0.20 mg/l in the Dhaleshwari river, Bangladesh. Raju *et al.*, (2013) reported 0.20µg/l in pre-monsoon and 0.53 µg/l in the post-monsoon season. It is very lower than our findings. Lead content also observed by Hussain *et al*., (2017) as high as 7.41µg/l. Lead concentrations are found to be too high in every sample analyzed in this study. Kidney failure patients reported more discomfort after drinking polluted water, particularly water containing lead. The essential element lead (Pb) is toxic even in trace amounts. It is imperative that efforts be made to decrease lead exposure from all sources, including drinking water, since there is no safe amount of lead exposure that will not negatively affect a child's brain development (Levallois *et al*., 2018).

Nickel

Nickel content ranged between the studied sites in the following order; S3 (0.08) >S1 (0.06) > S2 (0.04) in the post-monsoon season and below the detectable limit during monsoon season across studied sites (Fig. 2 and 3). Nickel content at site S3 during the post-monsoon season has crossed the limit of (0.02 mg/l) set by WHO (2017). It showed that this area has been polluted by Ni, due to the usage of nickel acetate in textile printing. Kumar *et al*., (2019) studied Ni concentrations in the river Ganga and reported it as 0.125 mg/l. In our study, higher Ni concentration was noted in S3 during the post-monsoon season.

Cadmium

Figure 2 and 3 showed that the concentration of Cd in the studied area varied as follows: S1 (0.01) > S3 (0.004) > S2 (BDL) and S3 (0.007) > S2 (0.005) > S1 (0.0034) in the post-monsoon and monsoon season respectively. According to the permissible limit of (0.005 mg/l) set by WHO (2017) our studied sites (S1) exceeded the limit. Ali *et al*., (2016) showed similar results for Cd in summer (6.46 µg/l) and winter (10.64 µg/l) season. However, Kumar et al. (2019) revealed 0.053 mg/l form river Ganga Hussain *et al*., (2017) reported 0.001-1.59 µg/l. Our findings revealed low concentrations of Cd than in monsoon season, this might be due to the dilution of river water by rain.

Arsenic

Arsenic contents in the studied area ranged as follows: S3 (0.06) > S2(0.04) > S1 (0.02) in the post-monsoon season (Fig. 2) and S1 (0.018) > S3 (0.016) > S2 (0.012) during monsoon (Fig.3). Figure 1 also depicted that arsenic is third heavy metal in high concentration followed by chromium and lead. Ali *et al*., (2016) reported the mean concentration of As content as 23.36 µg/l in summer and 34.46 µg/l in the winter season. Arsenic concentration was also studied by Hussain *et al*., (2017) and analyzed their concentration varies from 0.04 to 9.31µg/l. They reported that the high concentration of As and Pb makes river water unsafe for human consumption. Our study showed that arsenic content was crossing permissible limit of 0.01 mg/l WHO, 2017 at site S3. Besides, mean concentrations across the studied sites in post monsoon season crossed the permissible limit of 0.01 mg/l. It indicates river water is exposed to arsenic because of industrial effluents.

Selenium

Figure 2 and 3 showed that the selenium concentrations was in the following order of: S1, S3 (0.04) > S1 (0.02) in post-monsoon season and during monsoon season S3 (0.012) > S2 (0.008) > S1 (0.006). Based on concentration across studied sites, only S1 and S3 crossed the acceptable limit (0.02 mg/l) during post monsoon season. Rampley *et al.*, (2019) also reported very low selenium concentration from Buriganga river in Bangladesh and concentration ranged 0.175 – 0.873 µg/l in december month. There are many research studies about effluents of industrial spills cause serious problems of water pollution, especially the impact of distillery effluents and the ecology of Cauvery River was investigated. (Paramasivam and Sreenivsan, 1981).

Mercury

Mercury in the present study was reported from site S1 only during post- monsoon season and rest of the sites in both the seasons had mercury content below detection limits (Fig. 2 and 3). Site (S1) is the only who crossed the acceptable limit of (0.001 mg/l) as specified by WHO. From the catchments of site SI, the effluents from thermal power plants carry Hg along and mix it with river water. Rampley *et al*., (2019) also determined Hg concentration from river Buriganga, Bangladesh with concentration ranging between BDL – 0.024 µg/l, during December month.The cauvery river act as a source of drinking water, fishing and other domestic uses for the inhabitants. It is of immense importance that a periodical research and timely monitoring of the river water and sediments around the site area are very much needed.

Adsorption is a simple, efficient, and cost effective way for cleaning wastewater, among many others. The goal of this research was to develop a chemical and natural process for cleaning all types of wastewater, such as that generated by factories, hospitals, and homes. Charcoalation, electrocution, salination, and filtering via pebbles and sand are just a few of the methods we use to clean up our wastewater. First, there is need to heat some dry bamboo pieces for two to four hours before letting them cool. Collect the wastewater, and then flush it via activated charcoal. When the salt is sterile, the water may be run through it to purify it (NaCl). After this, a circuit is formed using batteries or cathode and anode to transmit electricity via the collected water. Once completed all of these steps, then pebbles, sand, and coal may be used to construct a system or setup. Filter paper goes at the bottom of any container, then activated charcoal, then sand and pebbles. Once the treated water is run through this system, the resulting liquid is completely clean.

CONCLUSION

The current study revealed that the heavy metal concentrations of copper and zinc are much higher than the threshold allowed by the World Health Organization. However, low levels of Iron, Lead, and Manganese were detected in the river water samples collected for the Study. The findings provided in this research point to hospital effluents dumped into municipal sewage without treatment as a possible source of contaminants. The samples potential danger to aquatic life has been confirmed by eco toxicological examinations. In addition to metals, a wide variety of chemicals present in untreated or partly treated effluent fluids may accumulate in sediments and contribute to their toxicity. The present findings lend credence to the idea that hospital effluents may benefit from the same cutting-edge technology used in today's industrial and municipal sewage treatment facilities.

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Fig. 2. Concentrations of heavy metals in water samples from different sampling sites during post monsoon season

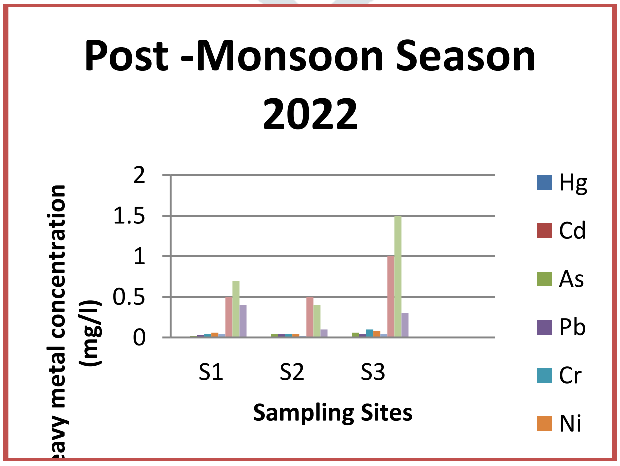


Fig. 3. Concentrations of heavy metals in water samples from different sampling sites during monsoon season

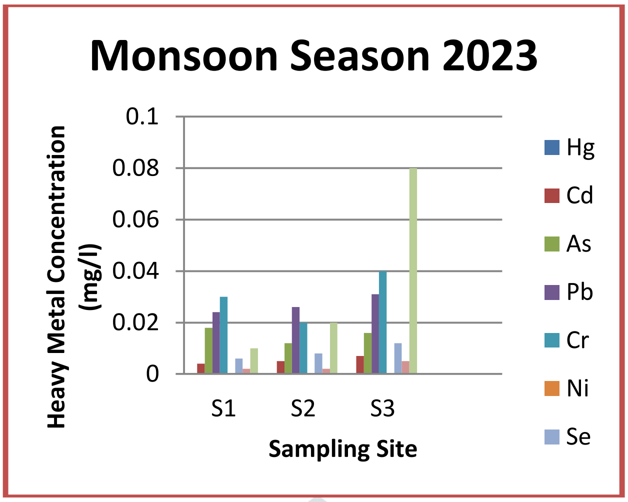
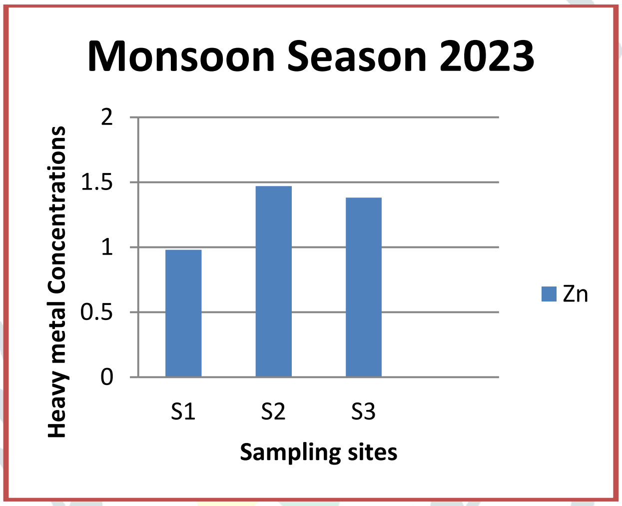


Fig. 4. Concentrations of heavy metal (Zinc) in water samples from different sampling sites during monsoon season



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