Heavy Metal Contamination in Water of the River Cauvery- A Case Study of Erode, Salem and Namakkal Districts, Tamil Nadu

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ABSTRACT

The presence of heavy metals in river water represents a serious environmental issue. The current study aimed to determine ten 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 Erode, Salem, and Namakkal 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 power stations, dyeing industries, tanneries, etc. Study area I was polluted with Pb, As, and Se during post-monsoon and with Pb and Cd in the monsoon season, due to the release of effluents from power plants, steel factories, and cement factories, etc. study area II was contaminated with Pb and Cr during post-monsoon and with Pb and Cd in the monsoon season, owing to the effect of effluents from dyeing industries. Study area III was dominated by Pb, Cd, and Cr during post-monsoon and Pb alone was present during monsoon season. Here leather and chemical industries were responsible for the release of wastewater into the river. Study area IV was heavily contaminated by Pb, Cd, As, Cr, and Ni during post-monsoon, and in the monsoon season Pb and As dominated the studied area of Cauvery river. The order of progression of mean metal concentration (mg/l) across the studied area during post-monsoon (2019) season was Zn (1.375) > Fe (0.1525) > Cu (0.125) > Cr (0.0825) >Pb (0.0575) > Ni (0.0325) > As (0.02) > Se (0.0175) > Cd (0.00575) > Hg (0.00125) and in monsoon season (2020) metal progression was Zn (1.205) > Fe (0.0625) >Pb (0.0325) > Cr (0.02775) > Cu (0.02625) > As (0.01875) > Se (0.0095) > Cd (0.00425) (mg/L). 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.

Keywords: *Heavy metals, Contamination, Cauvery river, Industrial effluents, anthropogenic activities*

INTRODUCTION

Water is an essential component of our day-to-day 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 (Gao *et al*., 2009; Nduka and Orisakwe, 2011) and at the same time natural processes like weathering, leaching from garbage also contributes to metal contamination in the aquatic environment (Tarra-Wahlberg *et al*., 2001; Jorda *et al*., 2002; Bai *et al*., 2011; Grigoratos *et al*., 2014; Martin *et al*., 2015 and Forstner, 1983). 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; Carlson, 2014; Bullen, 2014; Duruibe *et al*., 2007).

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 and Apostoli, 2002). 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 (Eisler, 1985; 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 metals are undergoing various changes during their transportation due to dissolution, precipitation, and sorption phenomena (Abdel-Ghani and Elchaghaby, 2007) which affect their performance and bioavailability (Nicolau *et al*., 2006 and Tongesayi *et al*., 2013). Sources of heavy metals and their impacts on human health are given in table 1.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; Vosyliene and Jankaite, 2006 and Ashraj, 2005).Since Cauvery river is one of the important source of water for irrigation as well as drinking. About 34 million liters per day is being supplied daily to the public in the Erode district. 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 different study areas around Erode, Salem, and Namakkal districts. The research work was carried during the post-monsoon season (December) in 2019 and the monsoon season (August) in 2020.

MATERIAL AND METHODS

Sampling sites

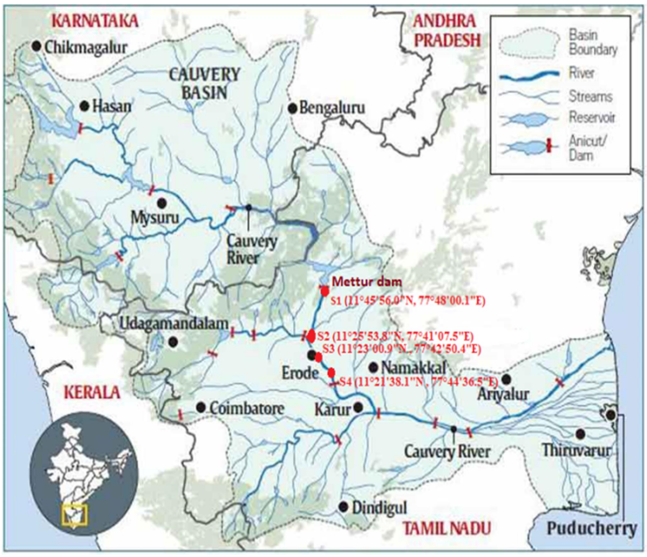

Fig. 1 Map showing sampling sites from the river Cauvery

Table 1. Sources of Heavy metals and their toxic effects on human health

Heavy metals	Sources	Toxic effects
Arsenic	Pesticides, fungicides, metal smelters, combustion of fossil fuels.	Coagulates protein, nerve inflammation, muscle weakness, malfunctioning of cell respiration, carcinogenic effect, neurotoxic effects.
Cadmium	Welding, electroplating, pesticides, fertilizers, batteries, nuclear fission plant, cadmium pigments, effluents from sewage treatment plants.	Renal failure, hyperactivity, softening of bones, slowed growth, muscle and joint pain, carcinogenic effect.
Chromium	Mining, paint, electroplating, textile, tannery industries	Kidney damage, liver failure, damage to the circulatory system, breakdown of nerve tissue, allergic reactions, neurotoxic effects.
Copper	Electroplating, pesticides, mining and smelting, agricultural and sewage sludge.	Diarrhea, nausea, headache, dizziness, stomach cramps, kidney damage.
Iron	Chemicals, fertilizers, pharmaceutics, pigments.	Arthritis, cancer, liver problems, diabetes, heart failure
Lead	Paint, pesticides, batteries, automobile emission, mining, burning of coal	Memory and concentration problems, high blood pressure, hearing problems, reproductive problems, digestive problems, carcinogenic effects.
Mercury	Pesticides, batteries, paper industries, thermal power plants.	Congenital malformations, abortion, gastrointestinal disorders, carcinogenic effect, gingivitis, stomatitis, neurological disorders.
Nickel	Electroplating, battery industries, mining works, burning of coal and oil, phosphate fertilizers, pesticides.	Hair loss, cancer risk, derma toxicity, decrease in body weights, irritation, skin diseases.
Selenium	Mining, refineries, agricultural runoff.	Anemia, bone stiffness, hair loss, blindness.
Zinc	Refineries, brass manufacture, metal plating, the immersion of painted idols	Psychical dysfunction, neurological disturbances, influences on the respiratory system, stomach damage, nausea, hyperactivity.

The 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. The primary use of this river is for household consumption, irrigation, and electricity generation. A total of four sampling sites were selected based on their importance like a thermal power plant, tanneries, dyeing industries, and textiles. The site I was Mettur in Salem district (11°45'56.0"N and 77°48'00.1"E). Here thermal power stations, steel plants, cement factories, spinning mills, chappal factories, oil bottling plants are present, and they released untreated effluents to the river

Cauvery. Site II was Kumarapalayam in Namakkal district (11°25'53.8"N and 77°41'07.5"E). It is described as “Capital of Powerloom” and “Textile town”.There are many dyeing industries, spinning mills, weaving units, export-oriented units are located. According to the 2011 census, 1767 household industries are detected in Kumarapalayam. Site III was Agraharam in Erode district (11°23'00.9"N and 77°42'50.4"E). In this study area leather, garments, textiles, chemical industries, oil companies, refineries are located. Site IV was Pallipalayam in Namakkal district (11°21'38.1"N and 77°44'36.5"E). Here 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 heavy metal concentration.

SAMPLE COLLECTION AND PRESERVATION

The water samples were collected during post-monsoon (December 2019) and monsoon (August 2020). 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).

Statistical analysis

The data was analyzed statistically by SPSS software. The mean and standard deviation of the heavy metal concentrations in water samples were calculated. Pearson correlation matrix(r) was used to identify the relationship between heavy metal concentrations during post-monsoon and monsoon.

$$r = \frac{\sum(X-\overline{X})(Y-\overline{Y})}{\sqrt{\sum(X-\overline{X})^2}\sqrt{(Y-\overline{Y})^2}}$$

Where, $\overline{X}$ = mean of X variable
$\overline{Y}$ = mean of Y variable

RESULTS AND DISCUSSION

Heavy metal contents in water samples

The mean concentration of different metals and their standard deviation were shown in table 2. The results revealed that the mean concentrations (mg/l)showed the following order; Zn (1.375) > Fe (0.1525) > Cu (0.125) > Cr (0.0825) >Pb(0.0575) > Ni (0.0325) >As(0.02) > Se (0.0175) > Cd (0.00575) > Hg (0.00125).Table 3 showed the concentrations of heavy metals in water samples collected from various sampling sites during the monsoon season (2020). The results revealed that the mean concentrations of heavy metals are in the following order: Zn (1.205) > Fe (0.0625) >Pb (0.0325) > Cr (0.02775) > Cu (0.02625) >As (0.01875) > Se (0.0095) > Cd (0.00425) > 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.

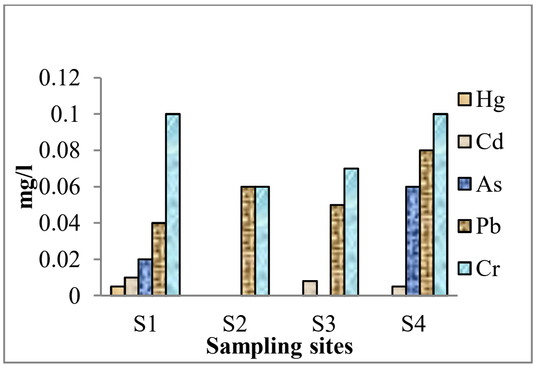

Fig. 2. Concentrations of heavy metals (Hg, Cd, As, Pb and Cr) in water samples from different sampling sites during post-monsoon season

Table 2. Heavy metal concentration (mg/l) in water samples at different sampling sites in the post-monsoon season (2019).

Sites	Hg	Cd	As	Pb	Cr	Ni	Se	Cu	Zn	Fe
S1	0.005	0.01	0.02	0.04	0.1	BDL	0.05	BDL	0.8	0.2
S2	BDL	BDL	BDL	0.06	0.06	BDL	0.02	BDL	0.4	0.05
S3	BDL	0.008	BDL	0.05	0.07	0.05	BDL	BDL	1	0.15
S4	BDL	0.005	0.06	0.08	0.1	0.08	BDL	0.5	3.3	0.21
WHO limits	0.001	0.005	0.01	0.05	0.05	0.1	0.02	1	5	0.3
Mean	0.00125	0.00575	0.02	0.0575	0.0825	0.0325	0.0175	0.125	1.375	0.1525
SD	0.0025	0.004349	0.028284	0.017078	0.020616	0.039476	0.023629	0.25	1.307351	0.073201

Table 3. Heavy metal concentration (mg/l) in water samples at different sampling sites in the monsoon season (2020)

Sites	Hg	Cd	As	Pb	Cr	Ni	Se	Cu	Zn	Fe
S1	BDL	0.007	0.016	0.02	0.04	BDL	0.013	BDL	BDL	BDL
S2	BDL	0.005	0.002	0.026	0.02	BDL	0.006	BDL	0.5	0.02
S3	BDL	0.002	0.019	0.034	0.021	BDL	0.009	0.005	1.32	0.08
S4	BDL	0.003	0.038	0.05	0.03	BDL	0.01	0.1	0.15	0.15
WHO limits	0.001	0.005	0.01	0.05	0.05	0.1	0.02	1	5	0.3
Mean	0	0.00425	0.01875	0.0325	0.02775	0	0.0095	0.02625	1.205	0.0625
SD	0	0.00222	0.01482	0.013	0.00932	0	0.00289	0.04922	1.31457	0.06752

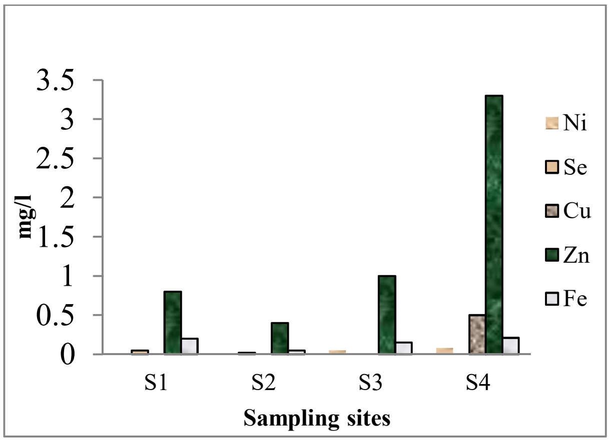

Fig. 3. Concentrations of heavy metals (Ni, Se, Cu, Zn, and Fe) in water samples from different sampling sites during post-monsoon season

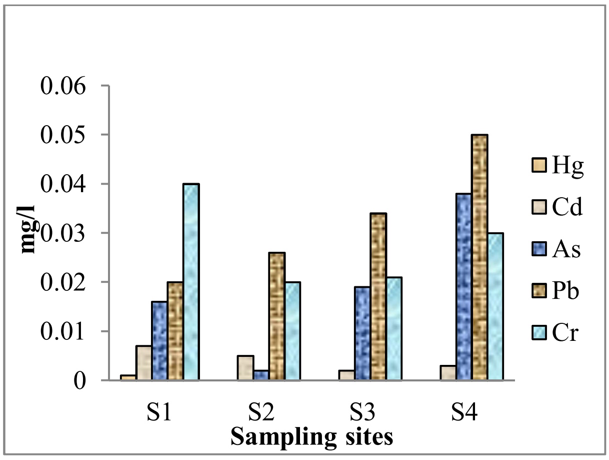

Fig. 4. Concentrations of heavy metals (Hg, Cd, As, Pb and Cr) in water samples during monsoon season

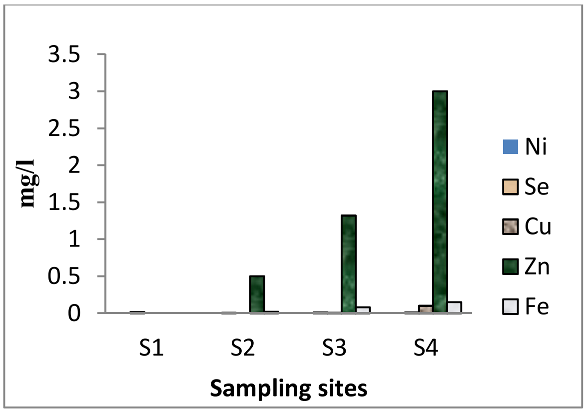

Fig. 5. Concentrations of heavy metals (Ni, Se, Cu, Zn, and Fe) in water samples from different sampling sites during the monsoon season.

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: S4 (3.3)> S3 (1.0) > S1 (0.8)>S2 (0.4) in post-monsoon season and in the following order S3 (1.32) > S2 (0.5) > S4 (0.15) > S1 (BDL) during monsoon season (Fig. 3 & 5). 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 Gholami (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). therefore water from river can be consumed, as such concentrations are not harmful to the human population, who are dependent on this river 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: S4 (0.21) > S1 (0.2) > S3 (0.15) > S2 (0.05) in post-monsoon season (Fig. 3). Figure 5 showed that iron ranged as follows; S4 (0.15) > S3 (0.08) >S2 (0.02) > S1 (BDL) in monsoon season. Very high levels of Fe (8.154 mg/l) content was recorded by Mahadev and Gholami (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.

Copper

Figure 3 and 5 showed that the copper concentrations ranged among sites in the following manner: S4 (0.5) > S1, S2, S3 (BDL) and S4 (0.1) > S3 (0.005) > S1, S2 (BDL) in the post-monsoon 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 Gholami (2010) reported 0.057 mg/l of Cu from river Cauvery, which was lower than our mean value of post-monsoon season but higher than the mean value of monsoon season. Bhuyan *et al*. (2019) also studied this metal concentration (0.12 mg/l) in the Brahmaputra river.

Chromium

The Chromium concentrations in the studied areas during the post-monsoon season (Fig. 2) were highest at site S1 and S4 (0.1) followed by S3 (0.07) > S2 (0.06). chromium also recorded higher concentration than other metals during post-monsoon season. During monsoon season the results revealed that S1 (0.04) > S4 (0.03) > S3 (0.021) > S2 (0.02) in monsoon season (Fig. 4). 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 S2, S3, and S4 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.

Lead

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 S4 followed by S2 (Fig. 2). Lead also showed considerable increase during post-monsoon season with values ranging from S4 (0.08) > S2 (0.06) > S3 (0.05) >S1(0.04) (Fig. 2). Figure 4 depicted that its concentration was higher than other metals, it progressively increased from S1 to S4 as:S4 (0.05) > S3 (0.034) > S2 (0.026) > S1 (0.02) 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.

Nickel

Nickel content ranged between the studied sites in the following order; S4 (0.08) > S3 (0.05) >S1, S2 (BDL) in the post-monsoon season and below the detectable limit during monsoon season across studied sites (Fig. 3 and 5). Nickel content at site S4 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. On the other hand, Liang *et al.* (2018) found Ni concentration between 0.05 – 10.05 µg/l in the Jiulongji river in China. In our study, higher Ni concentration was noted in S4 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 (0.008) > S4 (0.005) > S2 (BDL) and S1 (0.007) > S2 (0.005) > S4 (0.003) >S3 (0.002) 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, S3) 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 and 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: S4 (0.06) > S1 (0.02) > S1, S2 (BDL) in the post-monsoon season (Fig. 2) and S4 (0.038) > S3 (0.019) > S1 (0.016) > S2 (0.002) during monsoon (Fig.4). Figure 4 also depicted that arsenic is third heavy metal in high concentration followed b 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. Yeh *et al*. (2020) also found the arsenic concentration as 0.0151 mg/l in Houjing river, Taiwan. 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 S4. Besides, mean concentrations across the studied sites in both seasons crossed the permissible limit of 0.01 mg/l. It indicates river water is exposed to arsenic because of industrial effluents.

Selenium

Figure 3 and 5 showed that the selenium concentrations was in the following order of: S1 (0.05) > S2 (0.02) > S1, S2 (BDL) in post-monsoon season and during monsoon season S1 (0.013) > S4 (0.010) > S3 (0.009) > S2 (0.006). Based on concentration across studied sites, only S1 crossed the acceptable limit (0.02 mg/l) during 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.

Mercury

Mercury in the present study was reported from site SI only during post monsoon season and rest of the sites in both the seasons had mercury content below detection limits (Fig. 2 and 4). 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.

Seasonal variations of heavy metals

The correlation analysis of heavy metals between post-monsoon and monsoon season are represented in table 3. They are in the following manner: Cu (0.99) > Cr (0.89) >Pb (0.88) >As (0.87) > Se (0.51) > Fe (0.42) > Cd (0.11) > Hg, Ni (0) > Zn (-0.29).Copper and Zinc showed the high positive and negative relationship between post-monsoon and monsoon seasons respectively.

Table 3. Correlation between the post-monsoon and monsoon seasonal heavy metals.

	Hg	Cd	As	Pb	Cr	Ni	Se	Cu	Zn	Fe
Hg	**0**									
Cd		**0.11**								
As			**0.87**							
Pb				**0.88**						
Cr					**0.89**					
Ni						**0**				
Se							**0.51**			
Cu								**0.99**		
Zn									**-0.29**	
Fe										**0.42**

The sampling sites S2, S3, and S4 contain textile industries, printing, and dyeing industries. Such that heavy metals released from these industries does exhibit a high correlation between them. The sources and their impacts on human health by the studied heavy metals are already described in table1.

CONCLUSION

The presence of the excess amount of heavy metals in the water of the river Cauvery is an issue of major concern. Wastewater from various industries and other sources must be treated before discharge into the river. Awareness must be spread among the industrial workers, cleaners, municipality workers, and peoples living in and around the studied areas. Awareness must be created among people regarding toxic nature of metals studied, who depend on the river for various activities like drinking, fishing, etc. Further, regular monitoring of Cauvery river water and creation of general awareness about heavy metal pollution and its impacts on human health and the environment. Therefore, discharge of industrial and domestic sewage either should be avoided or modified for a better environment.

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