Section A -Research paper

SURFACE WATER OF THE ESTUARIES: HEAVY METAL DISTRIBUTION AND CONTAMINATION, SOUTHEAST INDIAN OCEAN COAST

Jakeer N[1], Arunadevi. S[1,*], Anuradha S. M[2]

[1*]PG & Research Department of Chemistry, Urumu Dhanalakshmi College, Kattur, Affiliated to Bharathidasan University, Tiruchirapalli, Tamilnadu, India.

2Department of Chemistry, T.K. Government Arts College (Grade – I), Virudhachalam – 606 001, Tamilnadu, India.

[1]Oricid-id:0000-0001-1666-5037

[1*]Oricid-id:0000-0001-6914-1985

aruna07ravi@gmail.com

parveenlucky86@gmail.com

anuradhapac@gmail.com

ABSTRACT:

Heavy metal toxicity studies were conducted using water samples collected in 2019 and 2020 from Parangipettai, Pazhaiyar, Poompuhar, Karaikal, and Velankanni. All of these samples were collected in the summer, either after or right before the monsoon hit. The samples were taken at a location a kilometre or two inlands from the shore, where two streams converged. Cadmium, chromium, copper, iron, nickel, lead, and zinc are the PPM heavy metal parameters. The sea confluence point has the highest concentration of iron pollution and heavy metals. The laboratory has implemented quality control and assurance procedures to guarantee the reliability of the results. Methods such as standard operating procedure adherence, standard calibration, blank analysis, etc. Analyzing duplicates and piecing together newly added components. Each experiment was repeated three times, with the average result used for analysis. To eliminate bias, we used the same statistical procedures on all samples. Each chemical element was analysed using the same methods as those used by the analytical laboratory.

Keywords: heavy metals, sea water, monsoon, iron, contamination

INTRODUCTION:

Industrial effluents, industrial boilers, leather tanning, paper manufacturing, petrochemical industries, and non-metallic mineral industries are the leading contributors to industrial pollution along the coast of Tamil Nadu. These installations discharge toxic metals and other contaminants either straight into the ocean's waterways or inadvertently into the land and air, where they are carried by precipitation and wind to the shoreline [1]. Heavy metals such as cadmium, copper, lead, mercury, nickel, and zinc are often found in Tamil Nadu's coastal waters (State report of TN, 2016). The water's content of the four metals varied significantly across the sample locations. The average amounts of Ni, Pb, and Cd in the samples were greater than those found in water from other parts of the Persian Gulf [2-4].

They are called "heavy metals" because their density is greater than that of water. Heavy metals have the potential to cause adverse health effects [5]. Because they are so soluble in water, heavy metals are easily absorbed by aquatic organisms. Previous research has shown that a variety of heavy metals may be discovered in the myocytes and hepatocytes of a variety of fish that dwell in contaminated marine ecosystems. Metals that make their way into the food chain could ultimately accumulate in the bodies of humans. Because the majority of heavy metals find extensive application in industry, workers at industrial facilities and people living in the area around such facilities are at danger of being exposed to heavy metals and being polluted by them. Heavy metals in the ecosystem is harmful to human health and also harm other forms of life [6-8].

Due to pollutant leakage into the water habitats, mercury and iron concentrations in caviar samples exceeded the Maximum Permissible Limits. Thus, it is advisable to monitor food product chemical levels [9]. Copper and aluminium levels are below safe limits, however the total quantity of contamination exceeds WHO guidelines for potable water. However, the water samples taken from bores in the Tirunelveli coastline area were determined to be completely free of contamination, with all metals falling below the safe limits established by WHO [10].

MATERIALS AND METHODS:

Sampling Area and Sampling Point

Samples of both the surface and the bottom waters of the estuary – Parangipettai (S1-S3); Pazhaiyar (S4-S6); Poompuhar (S7-S9); Karaikal (S10-S12) and Velankanni (S13-S15) were taken during the years 2019 and 2020 for the purpose of conducting heavy metal parameter determination research. Threee samples were taken from all the places labelled as S1 to S15, which were located at a confluencing point with the sea and between 1 and 2 kilometres distant from the sea.

Sample Collection

The samples of the surface water and the samples of the bottom water were obtained from each of the three unique places that were chosen, and the samples that were collected were then put in plastic canes for the purpose of storage. In order to minimise exposure as well as the effects of light and temperature, these sample bottles were hermetically sealed and kept in a dark setting at a constant temperature range from 4–10 degrees Celsius. Storage conditions were kept the same throughout.

Estimation of Heavy metal parameter level

Using flame atomic absorption spectrometry, the levels of the heavy metals lead, cadmium, iron, zinc, manganese, and copper were determined and analysed. Atomic absorption spectrometry, in conjunction with hydride and cold vapour generation, was used in order to find out whether or not arsenic and mercury were present in the sample. Inside of a graphite furnace, an atomic absorption spectrometry analysis was performed so that a determination could be made about the quantity of lead that was present. SOPs, calibration with standards, blank analysis reagents, and other laboratory quality assurance and quality control approaches have helped provide high-quality analytical results. These methods completed this assignment.

RESULTS AND DISCUSSION:

Estimation of heavy metals in 2019:

Heavy metals such as cadmium, chromium, copper, iron, nickel, lead, and zinc were analysed from water samples with concentrations expressed as mg/L or ppm. Distance from the sea and the location of the river's mouth were used to categorise the nature of the sample. Seasons have a major impact on the water's heavy metal content. There were traces of metals, but not enough to be certain.

Various estuary water samples reveal the presence of metals in the range of Fe>Zn>Cu>Cr>Ni>Pb>Cd throughout the 2019 monsoon season (Tabe1). Nickel, lead, and cadmium were metals that were barely detectable in a small number of samples (Fig.1). Metals were discovered to be present in the 2019 premonsoon season in the following order: Fe>Zn>Cu>Cr>Pb>Cd>Ni (Table 2). All of the samples had significant levels of iron, but the water from the Velankanni and Karaikal regions has very high levels of iron, ranging from 2.12 to 2.98 ppm (Fig. 2). According to the results of the metal contamination measurements made on 2019 summer, the range was Fe>Zn>Cu>Cr>Cd>Ni>Pb (Table 3). The values in the summer are different from those in the other seasons. Nickel was discovered to be in a high range between 0.84 and 1.64 ppm in Velankanni, a sample taken 2 km from the sea. Comparing all of the estuary water samples shows that iron (Fe) contamination occurs all year round.

According to Yousuf et al., (2021) employing benthic foraminifera as bio-indicators to measure the pollution of shallow marine ecosystems with heavy metals. Higher amounts of metals than those seen off Saudi Arabia's and Egypt's Red Sea coasts have also been discovered. The quantities of heavy metals in the research region may be related to human activity or terrestrial inflow [11].

The quantities of heavy metals in surface sediments were measured, and their temporal and geographical fluctuations, as well as their putative antecedent sources, were examined. A small uptick was seen in the levels of copper, lead, zinc, and cadmium. Overall, the Bohai Bay and the centre Bohai Sea had the highest populations. This suggested that there has been a substantial shift in the Bohai Sea's heavy metal supplies during the last several decades [12]. Ni exhibited potential ecotoxicological hazards, whereas Cu, Zn, Cr, Pb, and Cd were more likely to cause occasional unfavourable biological impacts than allowed by sediment quality standards (SQGs). There is a 21% chance that the total metal concentration is harmful [13]. The soils of mangroves in Tamilnadu not only function as a transporter of heavy metals to the seas that surround them, but they also actively absorb elements such as chromium, copper, iron, manganese, zinc, and lead. Several studies have shown that surface sediments from coastal locations may be helpful in determining the extent to which heavy metals contribute to pollution in marine environments [14].

Table 1: Heavy metal parameters levels in different estuary water samples – Monsoon 2019

S.No	Sampling site	Sample nature and other details	Heavy Metal parameters - Water (mg/L or PPM)						
			Cd	Cr	Cu	Fe	Ni	Pb	Zn
1	Parangipettai S1	Sea confluenicng point	0.17	0.16	0.37	1.89	0.12	0.13	1.12
2	Parangipettai S2	1 km away from sea	0.13	0.11	0.31	1.24	0.06	0.11	0.84
3	Parangipettai S3	2 km away from sea	0.10	0.06	0.21	0.94	BDL	BDL	0.58

4	Pazhaiyar S4	Sea confluenicng point	0.15	0.13	0.35	1.42	BDL	0.08	0.84
5	Pazhaiyar S5	1 km away from sea	0.12	0.10	0.24	0.98	BDL	0.06	0.64
6	Pazhaiyar S6	2 km away from sea	0.10	0.06	0.20	0.65	BDL	BDL	0.47
7	Poompuhar S7	Sea confluenicng point	0.11	0.09	0.24	0.90	BDL	0.09	0.68
8	Poompuhar S8	1 km away from sea	0.09	0.07	0.21	0.75	BDL	0.07	0.51
9	Poompuhar S9	2 km away from sea	0.07	BDL	0.14	0.55	BDL	BDL	0.33
10	Karaikal S10	Sea confluenicng point	0.19	0.18	0.45	2.12	0.13	0.14	1.16
11	Karaikal S11	1 km away from sea	0.15	0.15	0.34	1.84	0.11	0.12	0.94
12	Karaikal S12	2 km away from sea	0.12	0.11	0.25	1.12	0.08	0.10	0.71
13	Velankanni S13	Sea confluenicng point	0.22	0.20	0.51	2.98	0.13	0.15	1.64
14	Velankanni S14	1 km away from sea	0.18	0.17	0.42	1.87	0.12	0.13	1.24
15	Velankanni S15	2 km away from sea	0.15	0.14	0.37	1.42	0.10	0.11	0.84

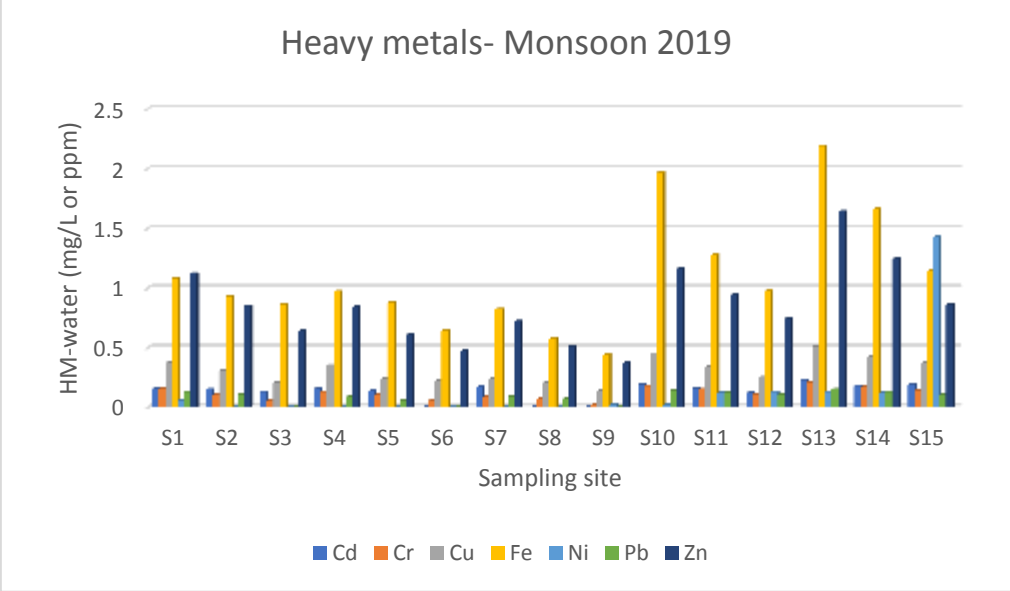

Fig. 1: Heavy parameters levels in different estuary water samples metals- Monsoon 2019

Table 2: Heavy metal parameters levels in different estuary water samples – Pre monsoon 2019

S.No	Sampling site	Sample nature and other details	Heavy Metal parameters - Water (mg/L or PPM)						
			Cd	Cr	Cu	Fe	Ni	Pb	Zn
1	Parangipettai S1	Sea confluenicng point	0.11	0.09	0.22	1.04	BDL	0.10	0.70
2	Parangipettai S2	1 km away from sea	0.09	BDL	0.16	0.89	BDL	0.09	0.53
3	Parangipettai S3	2 km away from sea	0.07	BDL	0.12	0.62	BDL	BDL	0.41
4	Pazhaiyar S4	Sea confluenicng point	0.12	BDL	0.20	0.84	BDL	0.06	0.52
5	Pazhaiyar S5	1 km away from sea	0.11	BDL	0.15	0.63	BDL	BDL	0.41
6	Pazhaiyar S6	2 km away from sea	BDL	BDL	0.10	0.50	BDL	BDL	0.31
7	Poompuhar S7	Sea confluenicng point	0.09	BDL	0.15	0.74	BDL	0.06	0.42
8	Poompuhar S8	1 km away from sea	BDL	BDL	0.11	0.49	BDL	BDL	0.30
9	Poompuhar S9	2 km away from sea	BDL	BDL	0.10	0.34	BDL	BDL	0.22
10	Karaikal S10	Sea confluenicng point	0.15	0.12	0.30	1.28	0.08	0.12	0.79
11	Karaikal S11	1 km away from sea	0.11	0.09	0.24	1.01	0.07	0.10	0.59
12	Karaikal S12	2 km away from sea	0.09	0.07	0.17	0.74	BDL	BDL	0.41
13	Velankanni S13	Sea confluenicng point	0.15	0.14	0.38	1.68	0.10	0.12	0.97
14	Velankanni S14	1 km away from sea	0.12	0.11	0.30	1.27	0.08	0.11	0.76
15	Velankanni S15	2 km away from sea	0.10	0.10	0.27	0.93	0.06	0.07	0.56

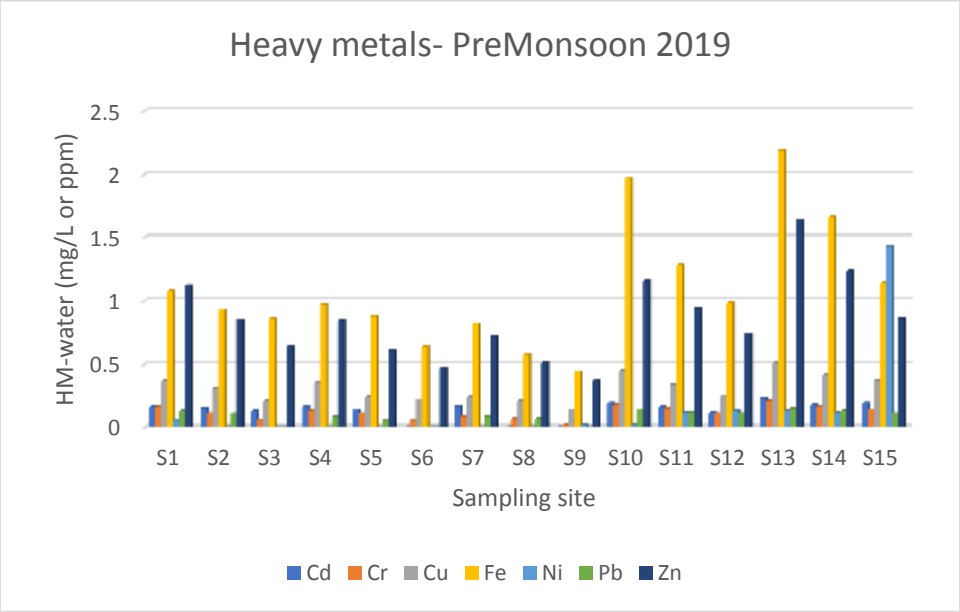

Fig. 2: Heavy parameters levels in different estuary water samples metals- Pre-Monsoon 2019

Table 3: Heavy metal parameters levels in different estuary water samples – Summer 2019

S.No	Sampling site	Sample nature and other details	Heavy Metal parameters - Water (mg/L or PPM)						
			Cd	Cr	Cu	Fe	Ni	Pb	Zn
1	Parangipettai S1	Sea confluenicng point	0.14	0.15	0.30	1.37	0.09	0.12	0.84
2	Parangipettai S2	1 km away from sea	0.12	0.10	0.26	1.04	0.06	0.10	0.70
3	Parangipettai S3	2 km away from sea	0.09	BDL	0.17	0.76	BDL	BDL	0.46
4	Pazhaiyar S4	Sea confluenicng point	0.13	0.12	0.26	0.97	BDL	0.06	0.68
5	Pazhaiyar S5	1 km away from sea	0.11	0.09	0.23	0.85	BDL	0.09	0.57
6	Pazhaiyar S6	2 km away from sea	0.08	BDL	0.16	0.60	BDL	BDL	0.40
7	Poompuhar S7	Sea confluenicng point	0.10	0.09	0.22	0.81	BDL	0.08	0.57
8	Poompuhar S8	1 km away from sea	0.08	0.06	0.18	0.64	BDL	0.06	0.44
9	Poompuhar S9	2 km away from sea	0.06	BDL	0.12	0.49	BDL	BDL	0.27
10	Karaikal S10	Sea confluenicng point	0.17	0.17	0.38	1.65	0.11	0.13	0.92
11	Karaikal S11	1 km away from sea	0.13	0.14	0.31	1.24	0.09	0.11	0.74
12	Karaikal S12	2 km away from sea	0.10	0.09	0.22	0.85	0.06	BDL	0.54
13	Velankanni S13	Sea confluenicng point	0.18	0.19	0.41	2.11	0.12	0.13	1.12
14	Velankanni S14	1 km away from sea	0.14	0.15	0.37	1.46	0.10	0.12	0.86
15	Velankanni S15	2 km away from sea	0.10	0.13	0.30	1.11	0.08	0.09	0.61

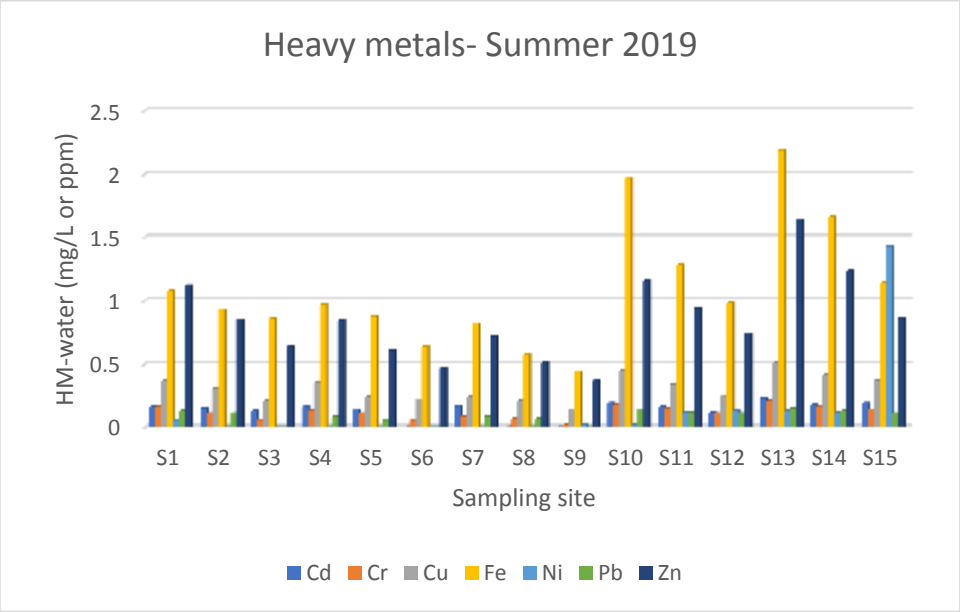

Fig. 3: Heavy parameters levels in different estuary water samples metals- Summer 2019

Estimation of heavy metals in 2020:

The water samples obtained from the summer of 2020 (Table 4) found to have different concentration of heavy metals in the decreasing order of Ni>Fe>Zn>Cu>Cd>Cr>Pb coastal area of velankanni (S15). The samples S10 to S14 has contamination range of Fe>Zn>Cu>Cd>Cr>Pb>Ni. The distant sample alone have high level of nickel contamination in water collected from velankanni during summer 2020. Other samples (S1-S9) found to have contamination in the order: Fe>Zn>Cu>Cd>Pb>Cr>Ni. This range shows that nickel was found below detectable level throughout summer this year. Lead and Chromium were also present in very low level and only at Parangipettai coastal area (Fig. 4).

Heavy metal parameters levels in different estuary water samples in pre monsoon season of 2020 (Table 5) obtained from sea confluence point found to be higher than that of other samples collected away from the sea (Fig. 5). Chromium, Lead and Nickel were found to be in negligible level. The analysis of samples obtained in post monsoon- 2020, shows that contamination of heavy metals in water along the south coastal area (S1-S14) occurs as Fe>Zn>Cu>Cd>Cr>Pb>Ni (Table 6, Fig. 6). Nickel contamination found to be in very high level from the samples collected away from sea only at velankanni (S15).

Large industrial facilities that are located in the coastal regions of Tamil Nadu frequently discharge their untreated effluents directly into the ocean or estuaries. This is due to the fact that the rivers of Tamil Nadu serve as the primary drainage system for a variety of different municipalities. Toxic levels of heavy metals, which are found in nature, have been released into the ocean as a result of growing industrialization and urbanisation. Heavy metals have a high atomic weight and density, and they also have a high atomic weight. In addition to trash from industry, the pollution is further exacerbated by sewage from cities and other types of garbage that cannot be broken down by natural processes. Heavy metals that are released into the environment might potentially bioaccumulate and biomagnify, which creates a risk for the marine life and the environments in which they live [15].

Table 4. Heavy metal parameters levels in different estuary water samples – Summer 2020

S.No	Sampling site	Sample nature and other details	Heavy Metal parameters - Water (mg/L or PPM)						
			Cd	Cr	Cu	Fe	Ni	Pb	Zn
1	Parangipettai S1	Sea confluenicng point	0.14	0.12	0.30	1.27	BDL	0.13	1.28
2	Parangipettai S2	1 km away from sea	0.11	BDL	0.21	1.03	BDL	0.11	0.84
3	Parangipettai S3	2 km away from sea	BDL	BDL	0.16	0.85	BDL	BDL	0.61
4	Pazhaiyar S4	Sea confluenicng point	0.13	BDL	0.27	1.10	BDL	BDL	0.84
5	Pazhaiyar S5	1 km away from sea	0.11	BDL	0.20	0.91	BDL	BDL	0.69
6	Pazhaiyar S6	2 km away from sea	BDL	BDL	0.14	0.72	BDL	BDL	0.57
7	Poompuhar S7	Sea confluenicng point	0.16	BDL	0.19	0.94	BDL	BDL	0.70
8	Poompuhar S8	1 km away from sea	BDL	BDL	0.16	0.66	BDL	BDL	0.58
9	Poompuhar S9	2 km away from sea	BDL	BDL	0.13	0.45	BDL	BDL	0.40
10	Karaikal S10	Sea confluenicng point	0.19	0.14	0.45	2.26	0.11	0.16	1.38
11	Karaikal S11	1 km away from sea	0.15	0.12	0.36	1.55	0.10	0.13	0.98
12	Karaikal S12	2 km away from sea	0.10	0.11	0.27	1.14	BDL	0.09	0.70
13	Velankanni S13	Sea confluenicng point	0.22	0.17	0.74	2.80	0.14	0.14	2.11
14	Velankanni S14	1 km away from sea	0.18	0.14	0.46	2.14	0.11	0.13	1.67
15	Velankanni S15	2 km away from sea	0.14	0.10	0.40	1.65	0.10	0.11	1.07

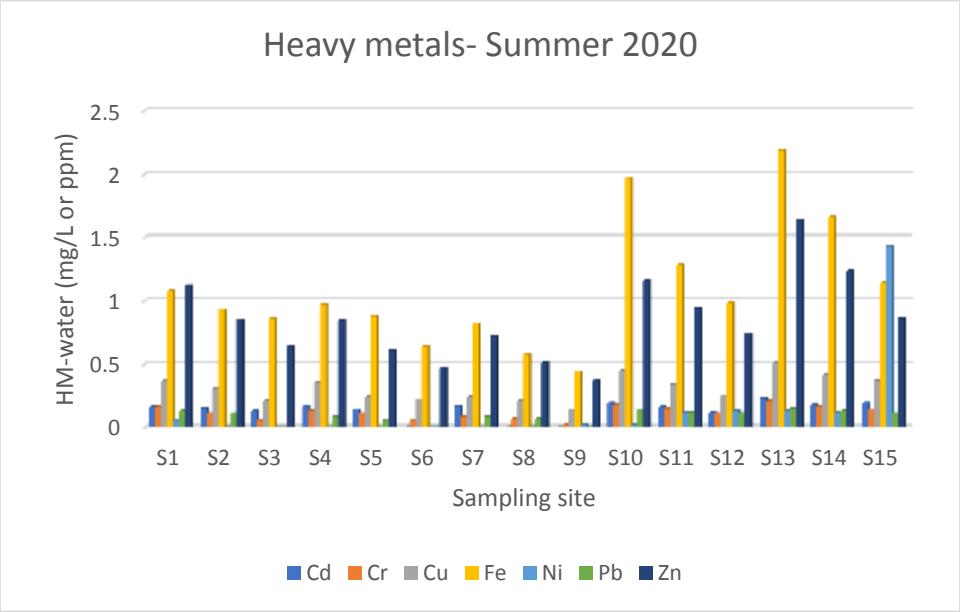

Fig. 4: Heavy parameters levels in different estuary water samples metals- Summer 2020

Table 5. Heavy metal parameters levels in different estuary water samples – Pre monsoon 2020

S.No	Sampling site	Sample nature and other details	Heavy Metal parameters - Water (mg/L or PPM)						
			Cd	Cr	Cu	Fe	Ni	Pb	Zn
1	Parangipettai S1	Sea confluenicng point	0.11	0.06	0.22	0.94	BDL	0.11	1.14
2	Parangipettai S2	1 km away from sea	0.08	BDL	0.11	0.88	BDL	0.10	0.67
3	Parangipettai S3	2 km away from sea	0.04	BDL	0.11	0.71	BDL	BDL	0.56
4	Pazhaiyar S4	Sea confluenicng point	0.12	BDL	0.21	0.97	BDL	BDL	0.68
5	Pazhaiyar S5	1 km away from sea	0.11	BDL	0.12	0.69	BDL	BDL	0.53
6	Pazhaiyar S6	2 km away from sea	BDL	BDL	0.08	0.62	BDL	BDL	0.48
7	Poompuhar S7	Sea confluenicng point	0.15	BDL	0.12	0.87	BDL	BDL	0.55

8	Poompuhar S8	1 km away from sea	BDL	BDL	0.09	0.51	BDL	BDL	0.44
9	Poompuhar S9	2 km away from sea	BDL	BDL	0.11	0.30	BDL	BDL	0.35
10	Karaikal S10	Sea confluenicng point	0.17	0.09	0.37	1.89	0.08	0.15	1.25
11	Karaikal S11	1 km away from sea	0.13	0.07	0.29	1.32	0.08	0.12	0.83
12	Karaikal S12	2 km away from sea	0.09	0.09	0.22	1.03	BDL	BDL	0.57
13	Velankanni S13	Sea confluenicng point	0.19	0.12	0.71	2.37	0.12	0.13	1.96
14	Velankanni S14	1 km away from sea	0.16	0.10	0.39	1.95	0.09	0.12	1.57
15	Velankanni S15	2 km away from sea	0.14	0.07	0.37	1.47	0.09	0.09	1.02

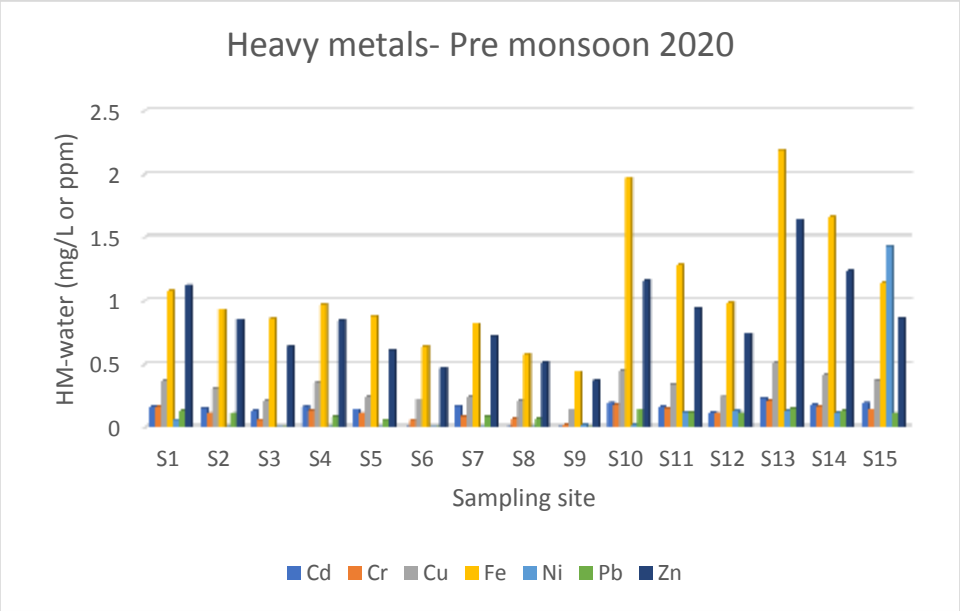

Fig. 5: Heavy parameters levels in different estuary water samples metals- PreMonsoon 2020

Table 6. Heavy metal parameters levels in different estuary water samples – Post monsoon 2020

S.No	Sampling site	Sample nature and other details	Heavy Metal parameters - Water (mg/L or PPM)						
			Cd	Cr	Cu	Fe	Ni	Pb	Zn
1	Parangipettai S1	Sea confluenicng point	0.16	0.16	0.37	1.08	0.06	0.13	1.12
2	Parangipettai S2	1 km away from sea	0.15	0.11	0.31	0.93	BDL	0.11	0.85
3	Parangipettai S3	2 km away from sea	0.13	0.06	0.21	0.86	BDL	BDL	0.64
4	Pazhaiyar S4	Sea confluenicng point	0.16	0.13	0.35	0.97	BDL	0.09	0.84
5	Pazhaiyar S5	1 km away from sea	0.14	0.11	0.24	0.88	BDL	0.06	0.61
6	Pazhaiyar S6	2 km away from sea	BDL	0.06	0.22	0.64	BDL	BDL	0.47
7	Poompuhar S7	Sea confluenicng point	0.17	0.09	0.24	0.82	BDL	0.09	0.72
8	Poompuhar S8	1 km away from sea	BDL	0.07	0.21	0.58	BDL	0.07	0.51
9	Poompuhar S9	2 km away from sea	BDL	0.02	0.14	0.44	0.02	BDL	0.37
10	Karaikal S10	Sea confluenicng point	0.19	0.18	0.45	1.97	0.02	0.14	1.16
11	Karaikal S11	1 km away from sea	0.16	0.15	0.34	1.28	0.12	0.12	0.94
12	Karaikal S12	2 km away from sea	0.12	0.11	0.25	0.98	0.13	0.11	0.74
13	Velankanni S13	Sea confluenicng point	0.23	0.21	0.51	2.19	0.13	0.15	1.64
14	Velankanni S14	1 km away from sea	0.18	0.17	0.42	1.66	0.12	0.13	1.24
15	Velankanni S15	2 km away from sea	0.19	0.14	0.37	1.14	1.43	0.11	0.86

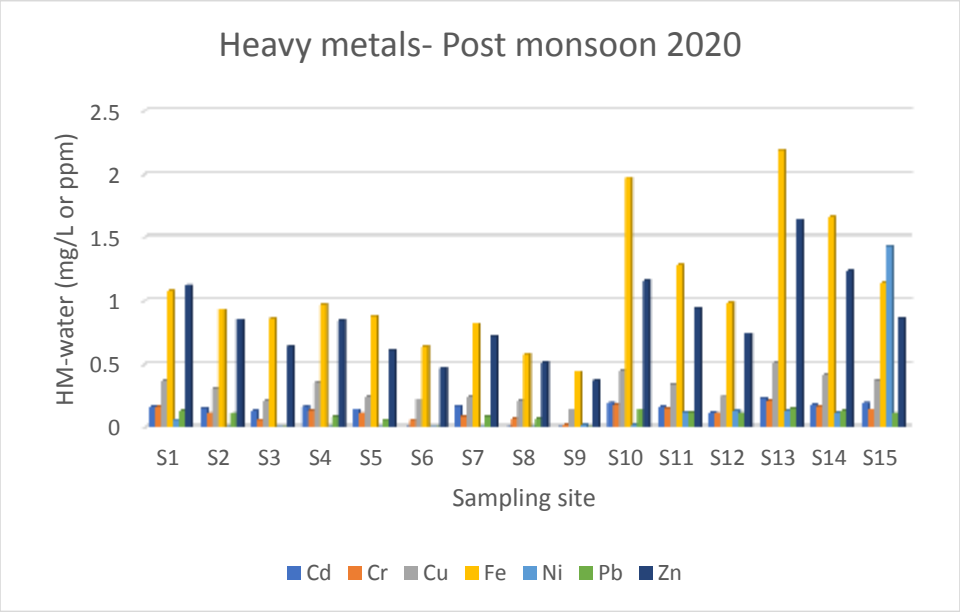

Fig. 6: Heavy parameters levels in different estuary water samples metals- Post Monsoon 2020

Jammel et al., (2012) determined the extent of the pollution problem in the Karaikal region and its surrounding areas, eight samples of ground water were taken throughout the monsoon, winter, and summer seasons and studied. It has been shown that, with the exception of lead, the levels of all of the other heavy metals are well below the acceptable range [16]. Estuarine and coastal sediments are particularly vulnerable because they act as a sink for heavy metals that have been absorbed by suspended particles and then sedimented. For this reason, the contaminant loads in estuarine and coastal sediments are much higher than in other environments. When paired with sediment, heavy metals tend to adsorb and aggregate on fine-grained particles, which subsequently travel towards depositional zones [17, 18].

CONCLUSION:

The water samples were tested in order to determine the heavy metal distribution as well as the pollution along the southeast coast of India. Iron may be found in high concentrations throughout the whole year in each of the four seasons starting in the year 2019. It was discovered that the levels of chromium, lead, and nickel were very insignificant. At the point where the sea and the river come together, heavy metal characteristics exhibit substantial levels of metal pollution. All of the samples taken two kilometres inland from the coast in the year 2020 showed that nickel had a significant level of toxicity in the Valankanni area. The distribution of metals and the pollution they cause is significantly influenced by environmental conditions as well as industrial effluents.

REFERENCES:

1. State of Environment Report for Tamil Nadu, Centre of Excellence in Environmental Economics, Madras School of Economics, Chennai. January 2016
2. Amir H. Charkhabi, Mohamad Sakizadeh and Gholamreza Rafiee, (2005). Seasonal Fluctuation in Heavy Metal Pollution in Iran's Siahroud GW. Environ Sci & Pollut Res, 12 (5) 264 – 270.

3. Pourang N, Nikouyan A, Dennis JH. Trace element concentrations in fish, surficial sediments and water from northern part of the Persian gulf. Environmental Monitoring and Assessment. 2005; 109: 293–316.
4. Ahamed Sulthan J, Mohamed Sihabudeen M, Sirajudeen J and Asrar Ahamed A, Variation in Physicochemical Characteristics of Groundwater Quality Between Taluks of Cuddalore District, Tamil Nadu. International Journal of Recent Scientific Research, 2016; 7(5), 11118-11122.
5. Kinuthia GK, Ngure V, Beti D, Lugalia R, Wangila A, Kamau L. Levels of heavy metals in wastewater and soil samples from open drainage channels in Nairobi, Kenya: community health implication. Sci Rep. 2020; 10: 8434. https://doi.org/10.1038/s41598-020-65359-5
6. Fergusson JE. The Heavy Elements: Chemistry, Environmental Impact and Health Effects (Oxford: Pergamon Press, 1990).
7. Sobhanardakani S, Tayebi L, Farmany A. Toxic metal (Pb, Hg, and As) contamination of muscle, gill and liver tissues of Otolithes ruber, Pampus argenteus, Parastromateus niger, Scomberomorus commerson and Onchorynchus mykiss. World Applied Sciences Journal. 2011; 14(10): 1453–1456.
8. Ahamed Sulthan J, Mohamed Sihabudeen M, Sirajudeen J and Asrar Ahamed A, Impact of Heavy Metals on Groundwater of Cuddalore District, Tamil Nadu. International Journal of Nano Corrosion Science and Engineering, 2015, 2 (5), 236-244.
9. Sobhanardakani S. Potential health risk assessment of heavy metals via consumption of caviar of Persian sturgeon. Mar Pollut Bull. 2017 Oct 15; 123 (1-2):34-38. doi: 10.1016/j.marpolbul.2017.09.033. Epub 2017 Sep 18. PMID: 28927825.
10. Puthiyasekar C, Neelakantan MA, Poongothai S. Heavy metal contamination in bore water due to industrial pollution and polluted and non-polluted sea water intrusion in Thoothukudi and Tirunelveli of South Tamil Nadu, India. Bull Environ Contam Toxicol. 2010 Dec; 85 (6):598-601. doi: 10.1007/s00128-010-0152-4. Epub 2010 Nov 17. PMID: 21082162.
11. Dr. N. Kesavan, "Exports and Imports Stagnation in India During Covid-19- A Review" GIS Business (ISSN: 1430-3663 Vol-15-Issue-4-April-2020).
12. Dr. D.Paul Dhinakaran, "Customers Delight towards Service Excellence in Indian Overseas Bank Chennai" International Journal of Business Education and Management Studies (IJBEMS), ISSN:2941- 9638, (Vol.3.Issue 1. 2020 (March).
13. Dr. M. Surekha, "A study on utilization and convenient of credit card" Journal of Positive School Psychology, http://journalppw.com, 2022, Vol. 6, No. 4, 5635–5645.
14. Dr.M.Rajarajn "Bus Operations of Service Quality in Tamil Nadu State Transport Corporation Limited, Kumbakonam" Asian Journal of Management,(A and V Publication),(ISSN:0976 – 495X), Volume: 4, Issue: 1, May, 2013.
15. Dr.Umesh U, "Impact Of Human Resource Management (HRM)Practices On Employee Performance" International Journal of Early Childhood Special Education (INT-JECSE), ISSN: 1308-5581 Vol 14, Issue 03 2022.

16. Dr. N. Kesavan, "Exports and Imports Stagnation in India During Covid-19- A Review" GIS Business (ISSN: 1430-3663 Vol-15-Issue-4-April-2020).
17. Dr. D.Paul Dhinakaran, "Customers Delight towards Service Excellence in Indian Overseas Bank Chennai" International Journal of Business Education and Management Studies (IJBEMS), ISSN:2941- 9638, (Vol.3.Issue 1. 2020 (March).
18. Dr. M. Surekha, "A study on utilization and convenient of credit card" Journal of Positive School Psychology, http://journalppw.com, 2022, Vol. 6, No. 4, 5635–5645.
19. Dr.M.Rajarajn "Bus Operations of Service Quality in Tamil Nadu State Transport Corporation Limited, Kumbakonam" Asian Journal of Management,(A and V Publication),(ISSN:0976 – 495X), Volume: 4, Issue: 1, May, 2013.
20. Dr.Umesh U, "Impact Of Human Resource Management (HRM)Practices On Employee Performance" International Journal of Early Childhood Special Education (INT-JECSE), ISSN: 1308-5581 Vol 14, Issue 03 2022.
21. Youssef M, El-Sorogy A, Al-Kahtany K, Saleh M. Benthic Foraminifera as Bio-indicators of Coastal Marine Environmental Contamination in the Red Sea-Gulf of Aqaba, Saudi Arabia. Bull Environ Contam Toxicol. 2021 Jun; 106(6):1033-1043. doi: 10.1007/s00128-021-03192-w. Epub 2021 Mar 31. PMID: 33791852.
22. Duan X, Li Y. Distributions and sources of heavy metals in sediments of the Bohai Sea, China: a review. Environ Sci Pollut Res Int. 2017 Nov; 24(32):24753-24764. doi: 10.1007/s11356-017-0330-6. Epub 2017 Oct 5. PMID: 28983722.
23. Gao X, Zhou F, Chen CT. Pollution status of the Bohai Sea: an overview of the environmental quality assessment related trace metals. Environ Int. 2014 Jan;62: 12-30. doi: 10.1016/j.envint.2013.09.019. Epub 2013 Oct 23. PMID: 24161379.
24. Ahamed Sulthan J, Mohamed Sihabudeen M, Sirajudeen J and Asrar Ahamed A. Assessment of Microbes Present in Ground Water of Cuddalore District, Tamil Nadu. World Journal of Pharmaceutical Research, 2018, Vol. 7, Iss. 8, 22-28.
25. Manikandan K, Felix N, Prabu E, Sudhan C, Kannan, B. Impacts of Heavy Metals in the Coastal Waters of Tamil Nadu. Journal of Aquaculture in the Tropics; New Delhi Vol. 33, Iss. 3/4, (Jul-Dec 2018): 143-154. DOI:10.32381/JAT.2018.33.3-4.4
26. Jameel AA, Sirajudeen J, Vahith RA. Studies on heavy metal pollution of ground water sources between Tamilnadu and Pondicherry, India. Pelagia Research Library - Advances in Applied Science Research. 2012; 3 (1):424-429
27. Zwolsman JJG, Eck BTM, Weijden CHV. Geochemistry of dissolved trace metals in the Scheldt estuary, southwestern Netherlands: impact of seasonal variability. Geochim. Cosmochim. Acta. 1997; 61: 1635–1652.
28. Chapman PM, Wang F, Janssen C, Persoone G, Allen HE. Ecotoxicology of metals in aquatic sediments binding and release bioavailability, risk assessment, and remediation. Can. J. Fish. Aquat. Sci. 1998; 55: 2221–2243.