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# Assessment of Heavy Metal Contamination in the Sediments of Musi River, Hyderabad

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**--------------------------------------------------------ABSTRACT--------------------------------------------------------**
*Musi River is one of the major tributaries of Krishna River in south India, which passes through Hyderabad, the capital city of Telangana State. Pollution due to heavy metal contamination in the sediments of Musi River is mainly because of anthropogenic activity which may have adverse effects on freshwater ecology of the river. The present study is confined to Gandipet (upstream of Hyderabad city) location to Wadapally (confluence of Musi River with Krishna River) for assessment of heavy metal contamination in the sediments in the Musi River due to the anthropogenic activities. It includes a systematic analysis of 7 heavy metals ie: As, Cr, Ni, Cd, Ba, Pb, Co at 12 locations along the river. The sediment samples were collected during summer, winter seasons of 2019, summer season of 2020 and winter season of 2021.The samples were analysed by (Inductively Coupled Plasma-Optical emission spectrometry) instrument following USEPA standard procedure.*
*The results of concentrations of all the7 heavy metals at Gandipet location (control station) are not detectable {ND} for both the seasons. The comparison of analysis results for other 11 locations during the summer and winter seasons indicates that there is an increase in the concentrations of Chromium, Nickel, Cadmium, Lead and Cobalt during winter season of 2021.There is no change in the concentrations of Arsenic and Barium in both the seasons. Further, the results were assessed with various indices as shown below for study and to evaluate the impacts of heavy metals on the sediments of Musi River.*
*Pollution load Index (PLI) is investigated for the Musi River.The locations at Moosarambagh, Nagole, Peerzadiguda, Pratap Singaram, Pillaypalli and are classified as "progressive deteriorative" as the PLI is >1. Whereas the locations of Bapughat, Rudravelly, Valigonda bridge, Kasaniguda, Bheemaram bridge and Wadapally locations classified under "base line pollution" category as the calculated PLI is 1. The PLI of Gandipet location is 0 and classified under the category of "no pollution".*
**Key Words:** *Musi River, Heavy metals, municipal solid waste, food chain, bio magnification, restoration, anthropogenic sources. Environmental Quality Indices.*

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## I. Introduction:

Heavy metal pollution of aquatic ecosystems is becoming a potential global problem. Metals are natural constituents in nature. In fact, during the last few decades, industrial and urban activities have contributed potentially to the increase of metals contamination. Many toxic metals such as arsenic, lead, nickel, cadmium, copper, mercury, zinc, and chromium present in untreated or allegedly treated industrial wastes (effluents) are carried by rivers in variable amounts (Singare et al.2011). Heavy metals discharged into a river system by natural or anthropogenic sources during their transport are distributed between the aqueous phase and sediments. The danger of heavy metals, unlike other pollutants, lies in their being nonbiodegradable and the accumulation in the earth's surface. Rivers receive sediment from various points and different sources which deposited at the bottom of the river which acts as both carriers and potential sources of biomagnifications (Theofanis et al 2001). The disposal of waste generated because of anthropogenic activities is a matter of serious concern. The waste management of industrial effluents and municipal wastes is highly essential for the abatement of environmental pollution (Brar et al 2000). The migration of elemental constituents from waste disposal sites to the ecosystem is a complex process and involves various geo-chemical activities. The elemental constituents can bio-magnify in animals and plants eventually making their way to humans through food chain (Abrahams 2002).

The heavy metals do not decay with time, unlike radionuclides and many organics, and hence long-term monitoring is also required. The heavy metals such as Cd, As and Pb are particularly important as they are not biodegradable and can accumulate in human vital organs, producing progressive toxicity (Alam et al 2003).

Heavy metals may be immobilized within the stream sediments and thus could be involved in the absorption, co precipitation and complex formation (Mohiuddin2010, Okafor2007). Sometimes they are co-adsorbed with other elements as oxides, hydroxides of Fe and Mn or may occur in particulate form (Awofolu2005, Mwiganga2005). Heavy metals concentrations in stream sediment compartments can be used to reveal the history and intensity of local and regional pollution (Nyangababo2005a). Analysis of pollutants in sediments is vital as they were adsorbed by material in suspension and by fine-grained particles (Rainey2003). Pekey (2006) demonstrated that the heavy metals tend to be trapped in aquatic environments and accumulate in sediments.

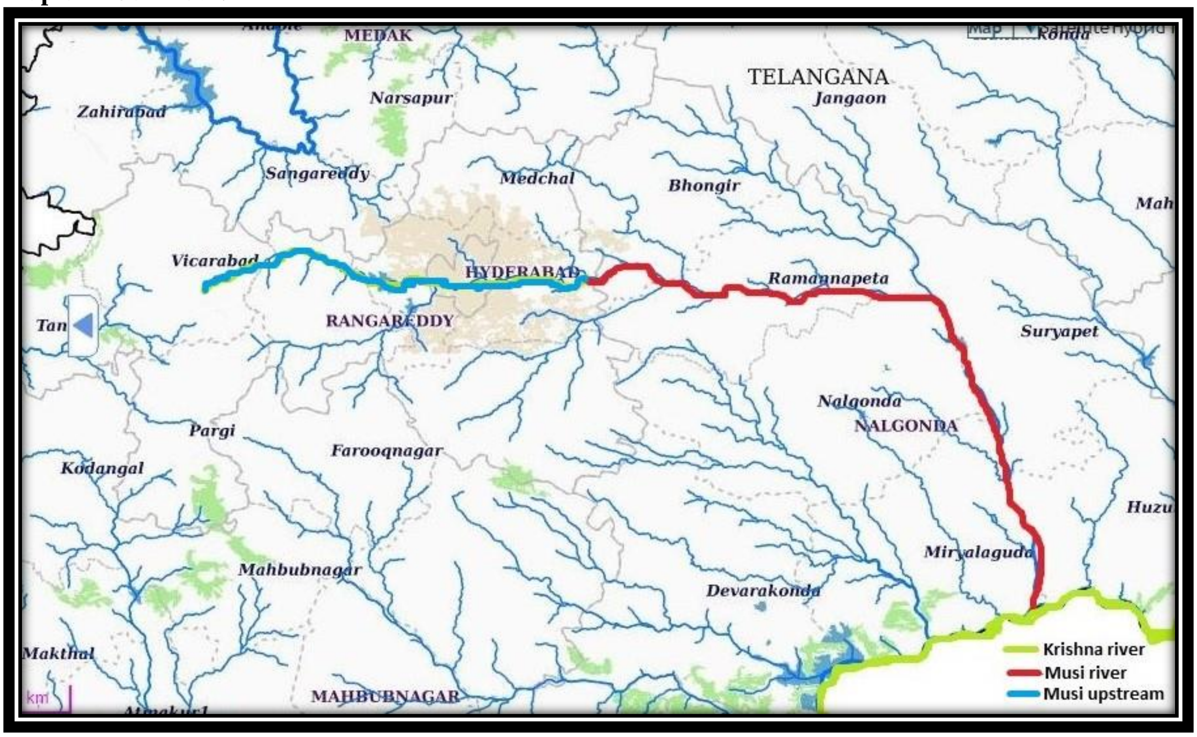
## II. Materials And Methods:

**Musi River:**

River Musi is a tributary of Krishna River and originates at Anathagiri hills near Vikarabad, 60 Km upstream of Hyderabad city which ultimately joins the Krishna River at Wadapally. The total length of Musi River is 240km.The Musi River basin is situated in the Deccan Plateau between Latitude:170 21' 59" N and Longitude: 78021'59" E. The Musi River flows into Himayath Sagar and Osman Sagar which are artificial lakes that acts as reservoirs for drinking water supply to the old city of Hyderabad.

River Musi flows into Hyderabad city as a clean resource and divides the historic old city from the new city. From Bapughat to Pratapsingarm locations along the river, it receives sewage and other solid waste dumping. The inorganic pollutants (heavy metals) are the greatest concern due to their presence in the sewage and other solid waste. The municipal solid waste dumps along the riverbanks are washed into river Musi with runoff water during monsoon. Hyderabad city has a population of 9.7 million in the metropolitan region (as per 2011census) and consumes over 500 MGD of water per day. The present sewage generation is 1450 MLD whereas the existing capacity of Sewage Treatment Plants (STP) is only 725.8 MLD. There is a gap of about 725 MLD and a high percentage of untreated sewage is discharged into river Musi.

**Map of Musi River:**




**Objective:**

1. To assess the heavy metal pollution in the sediments.
2. To investigate seasonal variations and evaluate the sediment quality using environmental quality indices.

**Methodology:**
The study area consists of Gandipet (Upstream of Musi at Hyderabad city) to Wadapally which is the confluence point of Musi with river Krishna.
Samples from 12 locations were collected from the riverbed during summer season (April) and winter season (November) of 2019, during summer season of May 2020 and winter season of Jan 2021 for study and analysis of 7 important heavy metals concentrations in the sediments.

**Sampling locations:**
12 Sample locations are selected along the musi river in the flow of direction from Gandipet which is control station and upstream of Hyderabad city till Wadapally (confluence station) at Krishna River. Details are given below.

| SNo | Location | Coordinates |
|---|---|---|
| **1** | Gandipet (Control Station). | $17^0$23'N$78^0$18'E |
| **2** | Bapughat. | $17^0$22'N$78^0$24'E |
| **3** | Moosarambagh. | $17^0$28'N$78^0$48'E |
| **4** | Nagole. | $17^0$31'N$78^0$55'E |
| **7** | Peerzadiguda. | $17^0$32'N$78^0$35'E |
| **6** | Pratapsingaram. | $17^0$38'N$78^0$66'E |
| **7** | Pillaypally. | $17^0$40'N$78^0$44E |
| **8** | Rudravelly | $17^0$41'N$78^0$78E |
| **9** | Valigonda Bridge. | $17^0$41'N$79^0$10'E |
| **10** | Kasaniguda (Solipet). | $17^0$41'N$79^0$31'E |
| **11** | Bheemaram bridge. | $17^0$40'N$79^0$40'E |
| **12** | Wadapally (before confluence with Krishna river). | $16^0$70'N$79^0$66'E |

**Sample Collection:**
Sediment samples (about 500gm each) were collected from 5 to10cm depth with Ekman dredger at 12 locations along the bank of Musi River covering all major nallah entry points in the Hyderabad city which are carrying the discharges. The samples were transferred into polythene bags by labelling the same with details like location, date, and time of collection.
**Preparation of sediment samples, digestion, and analysis:**
Sediment samples were air dried for a week and homogenized to fine powder and digested. All the sediment samples including a blank were digested with concentrated $HNO_3$ in microwave digester and carried out the analysis of heavy metals by ICP (Inductively Coupled Plasma Spectroscopy) instrument. (Make: Teledyne USA model no 1072). The obtained results were converted to mg/kg for assessment of contamination of heavy metals in the sediments.
**Environmental quality Indices and Statistcal analysis in Sediments:**
Environmental quality indices are a powerful tool for development, evaluation and conveying raw environmental information to decision makers, managers, technicians or for the public. Sediment quality values are useful to screen the potential for contaminants within the sediment to induce biological effects and compare sediment contaminant concentration with the corresponding quality guideline (Speneer2002). These indices evaluate the degree to which the sediment-associated chemical status might adversely affect aquatic organisms and are designed to assist sediment assessors and managers responsible for the interpretation of sediment quality (Caeiro2005). It is also helpful to rank and prioritizes the contaminated areas for further investigation (Farkas2007).
**Statistical analysis:**
Statistical analysis helps in interpreting the data and indicate patterns. The mean(m) is the sum of the total observations divided by the number of observations in a set of data. It calculates the central position of the data. The standard deviation (sd) is a measure of inconstancy, measuring the spread of the data and the relationship of the mean to rest of the data.

**A) Contamination Factor (CF):**
The contamination factor is the ratio of metal concentration in the sediment sample to the reference value of that metal (Barbieri 2016) The sediment sample contamination can be assessed using the contamination factor and can be calculated using the following relation.

$$\mathbf{CF} = \frac{\mathbf{(Cx)\ sediment}}{\mathbf{(Cx)\ reference}}$$

Where (Cx) sediment is the concentration of the element X in the sample and (Cx) reference is the concentration of the reference element. CF values are suggested for describing the contamination factor. Hakanson (1980) classified CF values into four classes.
Class 1: CF < 1: low contamination factor.
Class 2: CF1 ≤ Cf < 3: moderate contamination factor.
Class 3: CF 3≤ Cf < 6: considerable contamination factor.
Class 4: CF > 6: very high contamination factor.

**B) Contamination Degree (CD):**

The degree of contamination (CD) was defined as the sum of all contamination factors (CF). Ahdy and Khaled (2009) classified CD in terms of four grade ratings of sediments, i.e.

Class 1: Cd < 6: low degree of contamination.
Class 2: Cd 6 < 12: moderate degree of contamination.
Class 3: Cd 12 < 24: considerable degree of contamination.
Class 4: Cd > 24: very high degree of contamination indicating serious anthropogenic pollution.

**C) Pollution Load Index (PLI):**

PLI is used to assess the overall toxicity and quality status of the samples and contribution of the metals. To evaluate the overall degree of stream sediment metal contamination, the Pollution load Index (PLI) was calculated by the method proposed by Tomlinson et al (1980). It is determined by the calculation of the product of the n CF (contamination factor).

The Pollution Load Index (PLI) is a measure used to assess the overall level of pollution in a specific area, particularly for sediments or soils. It is calculated as the nth root of the product of the contamination factors (CF) for n number of metals. The formula for PLI is:

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n}$$

Where:
(CFn) is the contamination factor for the nth metal,
(n) is the number of metals being assessed.

Where CF is the contamination factor and n is the number of parameters. According to Mohiuddin (et al2010), zero (0) PLI value indicates 'perfect state of pollution '. If the PLI value is 1, it indicates that there is only baseline pollution is present in the locations. However, if PLI>1 it indicates 'progressive deterioration' status of the location. It provides a simple comparative means for assessing the level of heavy metal pollution.

The calculated values of Contamination Factor (CF), the degree of contamination (CD) and pollution load index (PLI) are given in the table 4.

**Table-1: Concentrations of Heavy metals in the sediments of Musi River for the year 2019 Summer (April) & winter (November)**

| **Location** | **As** mg/kg | | **Cr** mg/kg | | **Ni** mg/kg | | **Cd** mg/kg | | **Ba** mg/kg | | **Pb** mg/kg | | **Co** mg/kg | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **S** | **W** | **S** | **W** | **S** | **W** | **S** | **W** | **S** | **W** | **S** | **W** | **S** | **W** |
| Gandipet | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Bapughat | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 10 |
| Moosaram bagh | ND | ND | 14 | 17 | ND | 620 | ND | ND | ND | ND | 13 | 18 | ND | 500 |
| Nagole | ND | 10 | 16 | 34 | ND | 500 | ND | 10 | ND | 10 | 14 | 26 | 26 | 1300 |
| Peerzadi guda | ND | ND | 24 | 18 | 14 | 350 | ND | ND | ND | ND | 23 | 21 | ND | 700 |
| Pratap singaram | ND | ND | 16 | 16 | 12 | 900 | 10 | ND | ND | ND | 14 | 8 | ND | 500 |
| Pillaypally | ND | ND | ND | ND | ND | 1100 | ND | ND | ND | ND | 10 | 32 | ND | ND |
| Rudravelly | ND | ND | ND | ND | 10 | 600 | ND | ND | ND | ND | 10 | 10 | 13 | ND |
| Valigonda bridge | ND | ND | ND | ND | ND | 50 | ND | ND | ND | ND | ND | ND | ND | ND |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kasaniguda (Solipet) | ND | ND | ND | ND | ND | 21 | ND | ND | ND | ND | ND | ND | ND | ND |
| Bheemaram Bridge | ND | ND | ND | ND | ND | 20 | ND | ND | ND | ND | ND | ND | ND | ND |
| Wadapally | ND | ND | ND | 21 | ND | 18 | ND | ND | ND | ND | ND | ND | ND | ND |

**S=Summer; W=Winter; ND=Non detectable**

**Table-2: Concentrations of Heavy Metals in the sediments of Musi River during the year 2020(May) & 2021(Jan).**

| Location | As mg/kg | | Cr mg/kg | | Ni mg/kg | | Cd mg/kg | | Ba mg/kg | | Pb mg/kg | | Co mg/kg | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **S** | **W** | **S** | **W** | **S** | **W** | **S** | **W** | **S** | **W** | **S** | **W** | **S** | **W** |
| Gandipet | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Bapughat | ND | ND | ND | 1000 | 10 | ND | ND | ND | ND | ND | ND | ND | ND | 10 |
| Moosaram bagh | ND | ND | 20 | 2620 | ND | 13960 | 10 | 10 | ND | ND | 16.8 | 37.5 | 10 | 1000 |
| Nagole | 10 | 10 | 10 | 1800 | 10 | 3800 | 10 | 500 | ND | ND | 10 | 10 | 40 | 1800 |
| Peerzadi guda | ND | ND | 20 | 1000 | 10 | 1100 | 10 | 10 | ND | 10 | 20 | 20 | ND | 1000 |
| Pratap singaram | ND | ND | 20 | 2870 | 10 | 1850 | 10 | 10 | ND | ND | 20 | 20 | ND | 800 |
| Pillaypally | ND | ND | 20 | 2860 | 10 | 5940 | 10 | 10 | ND | ND | 12.2 | 42.2 | ND | 1000 |
| Rudravelly | ND | ND | ND | 20 | ND | 10 | ND | ND | ND | ND | ND | 10 | ND | ND |
| Valigonda bridge | ND | ND | ND | 25.6 | ND | 19.5 | ND | ND | ND | ND | ND | ND | ND | ND |
| Kasaniguda (Solipet) | ND | ND | ND | 20 | ND | 10 | ND | ND | ND | ND | ND | ND | ND | ND |
| Bheemaram Bridge | ND | ND | ND | 20 | ND | 20 | ND | ND | ND | ND | ND | ND | ND | ND |
| Wadapally | ND | ND | ND | 25.6 | ND | 19.5 | ND | ND | ND | ND | ND | ND | ND | ND |

**S=Summer; W=Winter; ND=Non detectable**

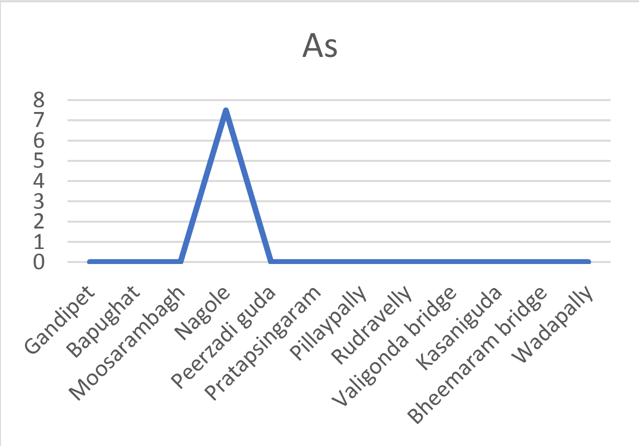
**Table-3: Contamination Factor (CF) values of heavy Metals in the sediments of Musi River for the year 2019 Summer (April) & winter (November), 2020 Summer and 2021 Winter.**

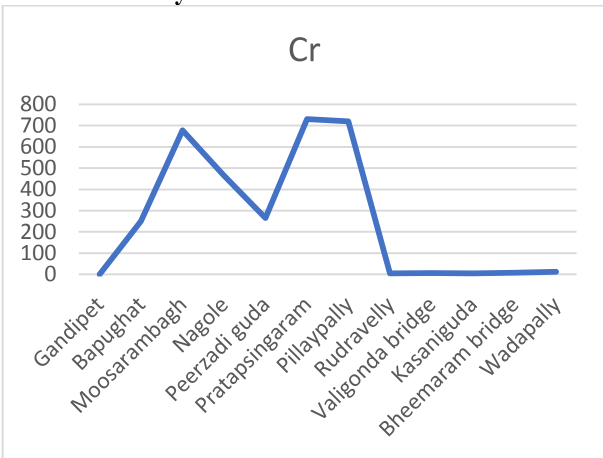
| Location | Arsenic (As) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2019 S** | **2019 W** | **2020 S** | **2021 W** | **mean** | **sd** | **CF** |
| Gandipet | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bapughat | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Moosarambagh | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Nagole | 0 | 10 | 10 | 10 | 7.5 | 5 | 2 |
| Peerzadi guda | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pratapsingaram | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pillaypally | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rudravelly | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Valigonda bridge | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kasaniguda | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bheemaram bridge | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wadapally | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Location** | **Chromium (Cr)** | | | | | | |
| | **2019 S** | **2019 W** | **2020 S** | **2021 W** | **mean** | **sd** | **CF** |
| Gandipet | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bapughat | 0 | 0 | 0 | 1000 | 250 | 500 | 11.11 |
| Moosarambagh | 14 | 17 | 20 | 2620 | 677.75 | 1301.5 | 29.68 |
| Nagole | 16 | 34 | 10 | 1800 | 465 | 890.1 | 20.67 |
| Peerzadi guda | 24 | 18.2 | 20 | 1000 | 265.55 | 489.6 | 11.80 |
| Pratapsingaram | 16 | 16 | 20 | 2870 | 730.5 | 1426.3 | 32.47 |
| Pillaypally | 0 | 0 | 20 | 2860 | 720 | 1426.7 | 32 |
| Rudravelly | 0 | 0 | 0 | 20 | 5 | 10 | 0.22 |
| Valigonda bridge | 0 | 0 | 0 | 25.6 | 6.4 | 12.8 | 0.28 |
| Kasaniguda | 0 | 0 | 0 | 20 | 5 | 10 | 0.22 |
| Bheemaram bridge | 10 | 0 | 0 | 20 | 7.5 | 9.574 | 0.33 |
| Wadapally | 0 | 21 | 0 | 25.6 | 11.65 | 1.3583 | 0.52 |

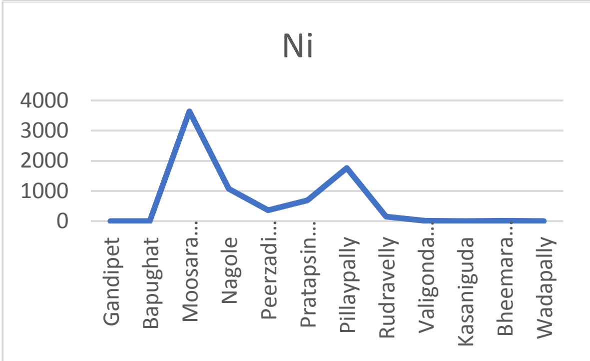
| Location | Nickel (Ni) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2019 S | 2019 W | 2020 S | 2021 W | mean | sd | CF |
| Gandipet | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bapughat | 0 | 0 | 10 | 0 | 2.50 | 5.00 | 0.15 |
| Moosarambagh | 0 | 620 | 0 | 13960 | 3645.00 | 6882.87 | 214.41 |
| Nagole | 0 | 500 | 10 | 3800 | 1077.50 | 1829.94 | 63.38 |
| Peerzadi guda | 14 | 350 | 10 | 1100 | 368.50 | 513.04 | 21.68 |
| Pratapsingaram | 12 | 900 | 10 | 1850 | 693.00 | 877.83 | 40.76 |
| Pillaypally | 0 | 1100 | 10 | 5940 | 1762.50 | 2832.44 | 88.97 |
| Rudravelly | 10 | 600 | 0 | 10 | 155.00 | 296.70 | 9.12 |
| Valigonda bridge | 0 | 50 | 0 | 19.5 | 17.38 | 23.61 | 1.02 |
| Kasaniguda | 0 | 21 | 0 | 10 | 7.75 | 10.01 | 0.46 |
| Bheemaram bridge | 0 | 20 | 0 | 20 | 10.00 | 11.55 | 0.59 |
| Wadapally | 0 | 18 | 0 | 19.5 | 9.38 | 10.84 | 0.55 |
| **Location** | **Cadmium (Cd)** | | | | | | |
| | **2019 S** | **2019 W** | **2020 S** | **2021 W** | **mean** | **sd** | **CF** |
| Gandipet | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bapughat | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Moosarambagh | 0 | 0 | 10 | 10 | 5.00 | 5.77 | 20 |
| Nagole | 0 | 10 | 10 | 500 | 130.00 | 246.71 | 520 |
| Peerzadi guda | 0 | 0 | 10 | 10 | 5.00 | 5.77 | 20 |
| Pratapsingaram | 10 | 0 | 10 | 10 | 7.50 | 5.00 | 30 |
| Pillaypally | 0 | 0 | 10 | 10 | 5.00 | 5.77 | 20 |
| Rudravelly | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Valigonda bridge | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Kasaniguda | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bheemaram bridge | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Wadapally | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| **Location** | **Barium (Ba)** | | | | | | |
| | **2019 S** | **2019 W** | **2020 S** | **2021 W** | **mean** | **sd** | **CF** |
| Gandipet | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bapughat | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Moosarambagh | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Nagole | 0 | 10 | 0 | 0 | 2.50 | 5.00 | 0.53 |
| Peerzadi guda | 0 | 0 | 0 | 10 | 2.50 | 5.00 | 0.53 |
| Pratapsingaram | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Pillaypally | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Rudravelly | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Valigonda bridge | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Kasaniguda | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bheemaram bridge | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Wadapally | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| | | | | | | | |
| **Location** | **Lead (Pb)** | | | | | | |
| | **2019 S** | **2019 W** | **2020 S** | **2021 W** | **mean** | **sd** | **CF** |
| Gandipet | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bapughat | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Moosarambagh | 13 | 18 | 16.8 | 37.5 | 21.33 | 10.99 | 1.21 |
| Nagole | 14 | 26 | 10 | 10 | 15.00 | 7.57 | 0.86 |
| Peerzadi guda | 23 | 21 | 20 | 20 | 21.00 | 1.41 | 1.2 |
| Pratapsingaram | 14 | 8 | 20 | 20 | 15.50 | 5.74 | 0.89 |
| Pillaypally | 10 | 32 | 12.2 | 42.2 | 24.10 | 15.60 | 1.38 |
| Rudravelly | 10 | 10 | 0 | 10 | 7.50 | 5.00 | 0.43 |
| Valigonda bridge | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Kasaniguda | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bheemaram bridge | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Wadapally | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| **Location** | **Cobalt (Co)** | | | | | | |
| | **2019 S** | **2019 W** | **2020 S** | **2021 W** | **mean** | **sd** | **CF** |
| Gandipet | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bapughat | 0 | 10 | 0 | 0 | 2.50 | 5.00 | 0.2 |
| Moosarambagh | 0 | 500 | 10 | 1000 | 377.50 | 476.12 | 30.2 |
| Nagole | 26 | 1300 | 40 | 1800 | 791.50 | 899.33 | 63.32 |
| Peerzadi guda | 0 | 700 | 0 | 1000 | 425.00 | 505.80 | 34 |
| Pratapsingaram | 0 | 500 | 0 | 800 | 325.00 | 394.76 | 26 |
| Pillaypally | 0 | 0 | 0 | 1000 | 250.00 | 500.00 | 20 |
| Rudravelly | 13 | 0 | 0 | 0 | 3.25 | 6.50 | 0.26 |
| Valigonda bridge | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Kasaniguda | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Bheemaram bridge | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |
| Wadapally | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0 |

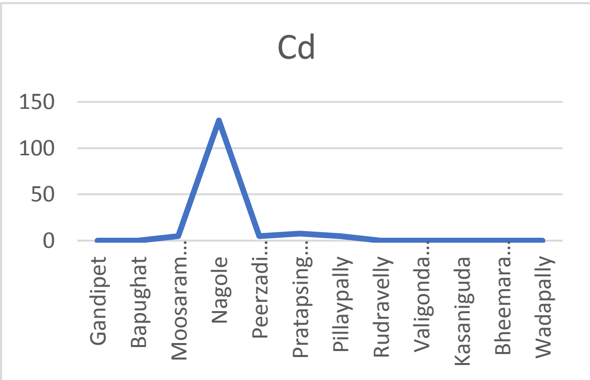
**Note:** For statistical evaluation of mean and standard deviation, the 'non-detectable' results in the table 1 & 2 were considered as "zero".

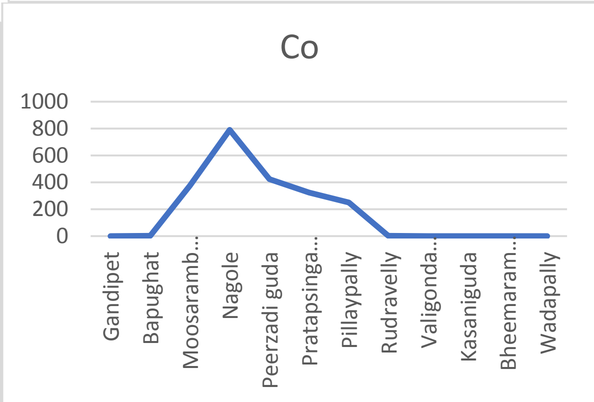
**Graphs Showing Mean values of Heavy Metals**

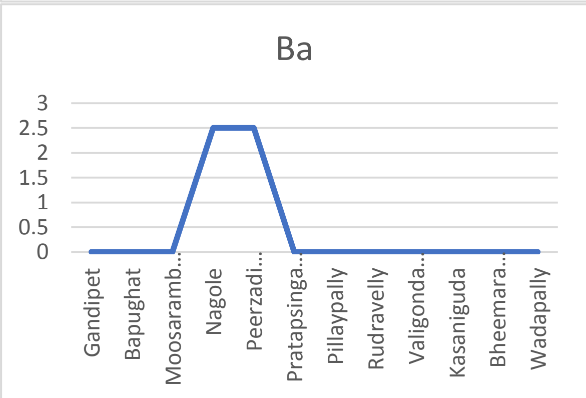


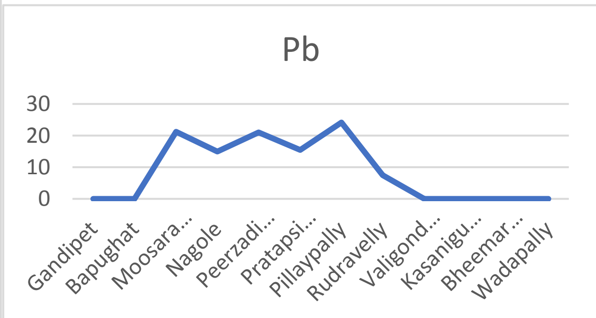



**Table 4: Contamination Factor (CF) of Metals, Degree of contamination (CD) and Pollution Load Index (PLI) of Musi River.**

| | Contamination Factor (CF) | | | | | | | CD | PLI |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **As** | **Cr** | **Ni** | **Cd** | **Ba** | **Pb** | **Co** | | |
| Gandipet | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bapughat | 0 | 11.11 | 0.15 | 0 | 0 | 0 | 0.2 | 11.46 | 0.693 |
| Moosarambagh | 0 | 29.68 | 214.41 | 20 | 0 | 1.21 | 30.2 | 295.5 | 21.552 |
| Nagole | 2 | 20.67 | 63.38 | 520 | 0.53 | 0.86 | 63.32 | 670.76 | 12.16 |
| Peerzadi guda | 0 | 11.8 | 21.68 | 20 | 0.53 | 1.2 | 34 | 89.21 | 6.928 |
| Pratapsingaram | 0 | 32.47 | 40.76 | 20 | 0 | 0.89 | 26 | 120.12 | 14.368 |
| Pillaypally | 0 | 32 | 88.97 | 20 | 0 | 1.38 | 20 | 162.35 | 17.348 |
| Rudravelly | 0 | 0.22 | 9.12 | 0 | 0 | 0.43 | 0.26 | 10.03 | 0.688 |
| Valigonda bridge | 0 | 0.28 | 1.02 | 0 | 0 | 0 | 0 | 1.3 | 0.534 |
| Kasaniguda | 0 | 0.22 | 0.46 | 0 | 0 | 0 | 0 | 0.68 | 0.318 |
| Bheemaram bridge | 0 | 0.33 | 0.59 | 0 | 0 | 0 | 0 | 0.92 | 0.441 |
| Wadapally | 0 | 0.52 | 0.55 | 0 | 0 | 0 | 0 | 1.07 | 0.534 |

**Table 5: Classification of Contamination Factor (CF) of Musi River**

| Location | As | Cr | Ni | Cd | Ba | Pb | Co | Class | Category |
|---|---|---|---|---|---|---|---|---|---|
| Gandipet | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Low |
| Bapughat | 0 | 11.11 | 0.15 | 0 | 0 | 0 | 0.2 | 4 | Very high |
| Moosarambagh | 0 | 29.68 | 214.41 | 20 | 0 | 1.21 | 30.2 | 4 | Very high |
| Nagole | 2 | 20.67 | 63.38 | 520 | 0.53 | 0.86 | 63.32 | 4 | Very high |
| Peerzadi guda | 0 | 11.8 | 21.68 | 20 | 0.53 | 1.2 | 34 | 4 | Very high |
| Pratapsingaram | 0 | 32.47 | 40.76 | 20 | 0 | 0.89 | 26 | 4 | Very high |
| Pillaypally | 0 | 32 | 88.97 | 20 | 0 | 1.38 | 20 | 4 | Very high |
| Rudravelly | 0 | 0.22 | 9.12 | 0 | 0 | 0.43 | 0.26 | 4 | Very high |
| Valigonda bridge | 0 | 0.28 | 1.02 | 0 | 0 | 0 | 0 | 1 | Low |
| Kasaniguda | 0 | 0.22 | 0.46 | 0 | 0 | 0 | 0 | 1 | Low |
| Bheemaram bridge | 0 | 0.33 | 0.59 | 0 | 0 | 0 | 0 | 1 | Low |
| Wadapally | 0 | 0.52 | 0.55 | 0 | 0 | 0 | 0 | 1 | Low |

**Table 6: Classification of Degree of Contamination (CD)and PLI of Musi River**

| Location | Degree of Contamination (CD) | | | Pollution Load Index (PLI) | | |
|---|---|---|---|---|---|---|
| | **CD** | **Class** | **Category** | **PLI** | **Class** | **Category** |
| Gandipet | 0 | 1 | Low | 0 | 0 | No pollution |
| Bapughat | 11.46 | 2 | Moderate | 0.693 | 1 | Base line Pollution |
| Moosarambagh | 286.5 | 4 | Very high | 21.552 | >1 | Progressive deterioration |
| Nagole | 670.76 | 4 | Very high | 12.16 | >1 | Progressive deterioration |
| Peerzadi guda | 89.21 | 4 | Very high | 6.928 | >1 | Progressive deterioration |
| Pratapsingaram | 120.12 | 4 | Very high | 14.368 | >1 | Progressive deterioration |
| Pillaypally | 162.35 | 4 | Very high | 17.348 | >1 | Progressive deterioration |
| Rudravelly | 10.03 | 2 | Moderate | 0.688 | 1 | Base line Pollution |
| Valigonda bridge | 1.3 | 1 | Low | 0.534 | 1 | Base line Pollution |
| Kasaniguda | 0.68 | 1 | Low | 0.318 | 1 | Base line Pollution |
| Bheemaram bridge | 0.92 | 1 | Low | 0.441 | 1 | Base line Pollution |
| Wadapally | 1.07 | 1 | Low | 0.534 | 1 | Base line Pollution |

**Table 7: Evaluation of Contamination Factor (CF), Degree of Contamination (CD) and Pollution Load Index (PLI) of Musi River**

| Location | Contamination Factor (CF) | | Degree of Contamination (CD) | | Pollution Load Index (PLI) | |
|---|---|---|---|---|---|---|
| | **Class** | **Category** | **Class** | **Category** | **Class** | **Category** |
| Gandipet | 0 | Low | 1 | Low | 0 | No Pollution |
| Bapughat | 4 | Very high | 2 | Moderate | 1 | Base line Pollution |
| Moosarambagh | 4 | Very high | 4 | Very high | >1 | Progressive deterioration |
| Nagole | 4 | Very high | 4 | Very high | >1 | Progressive deterioration |
| Peerzadi guda | 4 | Very high | 4 | Very high | >1 | Progressive deterioration |
| Pratapsingaram | 4 | Very high | 4 | Very high | >1 | Progressive deterioration |
| Pillaypally | 4 | Very high | 4 | Very high | >1 | Progressive deterioration |
| Rudravelly | 4 | Very high | 2 | Moderate | 1 | Base line Pollution |
| Valigonda bridge | 1 | Low | 1 | Low | 1 | Base line Pollution |
| Kasaniguda | 1 | Low | 1 | Low | 1 | Base line Pollution |
| Bheemaram bridge | 1 | Low | 1 | Low | 1 | Base line Pollution |
| Wadapally | 1 | Low | 1 | Low | 1 | Base line Pollution |

**D) Results and discussion:**

The results of concentrations of heavy metals at all the 12 locations were compiled and provided in the tables 1 & 2. Contamination factor (CF) of all the locations is provided in the table 3. The values of Contamination factor, degree of contamination and pollution load index are compiled in the table 4.

The classification of Contamination factor (CD) for all the locations is provided in the table 5. Similarly, the classification for degree of contamination (CD) and classification of pollution load index (PLI) is provided in the table 6. All the values of Contamination factor, degree of contamination and pollution load index are evaluated in the table 7.

**i) Assessment of contamination of Musi River as per Contamination Factor (CF) and Degree of Contamination (CD):**

Maximum value of contamination factor 214.41 for Nickel (Table 4) is observed for the sediment at Moosarambagh location during the winter season of 2021, while minimum CF value of 0.15 for Nickel is observed at Bapughat for summer season of 2020. At Nagole location, the maximum CF of 520 for Cadmium is observed during the winter season of 2021.

Locations of Bapughat, Moosaram bagh,,Nagole, Peerzadiguda, Pratapsingaram, Pillaypally, and Rudravelly are categorized under "Very High" as the CF values are 4.

Highest degree of contamination (CD) value of 670.76 is observed at Nagole location and lowest value of 0.68 is observed at Kasaniguda location. Bapughat and Rudravelly locations are categorised under "moderate" as the CD values are 2. Moosarambagh, Nagole, Peerzadiguda, Pratap Singaram, Pillaypalli locations are categorised as "very high" as the observed CD values are 4.

**ii) Assessment of contamination of Musi River as per Pollution Load Index (PLI):**

Pollution load Index (PLI) values for the investigated stations are illustrated in Table 6.

Moosarambagh, Nagole, Peerzadiguda, Pratap Singaram, Pillaypalli are classified as "progressive deteriorative" locations as the PLI is >1. Bapughat, Rudravelly, Valigonda bridge, Kasaniguda, Bheemaram bridge and Wadapally locations are classified under "base line pollution" category. The PLI of Gandipet is classified under the category of "no pollution".

## III. Conclusion

Contamination factor and degree of contamination, pollution load index indices were successfully applied for the assessment of heavy metal contamination in the sediments of Musi River. Pollution load index (PLI) derived from contamination factors shows that the sampling locations at Moosarambagh, Nagole, Peerzadiguda, Pratap Singaram and Pillaypalli recorded PLI >1 which indicates that these locations are under the category of "progressive deterioration". It is also noticed that after Pillaypalli location, the PLI values are indicating "base line pollution" (PLI as 1) category may be due to the movement of polluted sediments till Rudravelly location of Musi River.

The contamination factor (CF) for the locations at Bapughat, Moosarambagh, Nagole Peerzadiguda, Pratapsingaram, Pillaypalli and Rudravelly is indicating "very high" category pollution status. There is significant increase in the values of contamination factor (CF)and degree of contamination (CD) during winter season of 2021. This may be attributed to the "flash floods" occurred during October 2020.A detailed study of sediments is required for ascertaining the correlation between heavy metals, various anthropogenic effects, and natural resources.

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