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# Assessment of heavy metal pollution in Son river ecosystem at Diya Pipar Ghat, Shahdol (M.P.) India

**Aradhana Verma and Mohd. Shamsul Haque**

**Abstract**
The study was conducted to determine the seasonal changes of heavy metals (Cu, Cd, Fe, Mn, Ni and Zn) in Son river at Diya Pipar Ghat. The river water is pullulated due to effluents of paper mill discharge. For the study period four stations were selected. The study concludes that the water quality of Son river at Diya Pipar ghat is polluted as some of the results are above permissible limits. The paper mill discharge, agriculture waste and continuous dumping of waste materials are affecting the water quality of this ghat. The toxicological implications of this finding in relation to aquatic ecosystem and human health are discussed. There is considerable need for better understanding of this ghat can be managed effectively.

**Keywords:** Assessment, heavy metal, pollution, Son river

## Introduction
The air pollution from heavy metals has changed how these materials move and cycle in nature. (Azimi *et al.* 2003; Friedland & Miller 1999) [1-2]. The extensive influence of pollutant aerosols transported through the atmosphere over long distances on terrestrial ecosystems has been extensively studied. However, it is only recently that the attention has turned towards the consequences of airborne pollutant aerosols on inland water bodies (Pandey & Pandey 2009a; Thornton & Dise 1998) [3-4]. In India, the data so far available on these lines have been mainly confined to acidic depositions (Kumar *et al.* 2001 and Pandey *et al.* 2010) [5-6].

Water pollution and the presence of harmful substances in water sources have become pressing concerns in today's world, impacting agriculture, households, and industries alike. Among these hazardous substances, metals hold significant importance. In recent times, numerous water bodies in India have experienced heightened levels of heavy metal contamination due to the rise in atmospheric deposition and human activities near these aquatic environments. Increasing awareness of ecological hazard of toxic metals from urban and industrial sources has involved considerable interest in the study of levels and fate of heavy metals in the aquatic environment (Ahmed *et al.*, 2003) [7]. The potential toxic metal elements such as chromium, lead, copper, zinc etc., are identified to cause health hazards in animals (Lowe, 1970; Bryan, 1976; Sivakumar *et al.*, 2001) [8-10]. It is imperative to acquire knowledge regarding the concentration of heavy metals in both the trophic levels and sediments of the aquatic ecosystem.

The indiscriminate release of pollutants stemming from diverse industries, transportation, and the combustion of fossil fuels is progressively contaminating both aquatic and terrestrial habitats (Issa *et al.*, 1995) [11]. The presence of contaminated water discharges, whether from specific sources or from general pollution, presents a grave threat to both the environment and human well-being. Often, waste deposited on land is carried by rainwater into natural bodies of water, resulting in a significant influx of pollutants from human activities. Methods for addressing the issue of metal-contaminated soils and wastewater through physical and electrochemical treatments are not only costly but also offer limited success. In addition, they commonly produce hazardous by-products (Qian *et al.*, 1999) [12].

The persistent presence of heavy metals and industrial pollutants, unlike organic substances, poses a significant challenge as they accumulate in various environmental components such as water, soil, sediments, and organisms. Undoubtedly, the contamination of water sources by heavy metals is a crucial issue in today's global landscape.

The existence of toxic metals in ponds, ditches, and rivers profoundly impacts the livelihoods of local communities who rely on these vital water reservoirs to meet their daily needs (Rai *et al.*, 2002) [13]. The primary origins of metals in water stem from the erosion of minerals. Nevertheless, the levels of metals and their resulting effects can undergo significant alteration through their interaction with other components of natural water. Consequently, it is imperative to possess an understanding of heavy metal concentrations in order to gauge water pollution levels accurately and ascertain the baseline values of metal concentrations in the corresponding areas (Hansen *et al.*, 1995) [14].

## Materials and Methods

### Study site

The Shahdol district lies in the north-east part of Madhya Pradesh extending from 29°39'28" and 24°16'13" North latitude and from 80°32'56" to 82°12'21" East longitude approximately. The region lies in the heart of the country. The district is surrounded by Sone river and Rewa district in North, Mandla, in South Sidhi, Anuppur in Surguja East and Umaria and Satna in West. It is situated 489 meter above of the sea surface.

Diya Pipar Ghat is located in Sohagpur tehsil of Shahdol district in Madhya Pradesh, India. It is situated 16km away from Shahdol, which is both district & sub-district headquarter of Diya Pipar ghat. For the study of seasonal variations in heavy metal concentration, four study sites A, B, C and D were selected from Son river at Diyapipar ghat.

### Data Analysis

Samples were collected and stored following the Standard Methods for the Examination of Water and Wastewater (APHA, 2005) [15]. Water samples were sampled in jerry canes and the metal concentration was estimated using Varian Model Spectra AA-250 plus Atomic Absorption Spectrophotometer.

## Results and Discussion

To study the seasonal variation in heavy metals, four site of Son river were (at Diyapipar ghat) designated as A, B, C and D were selected depending upon the water. Three replicates data were summarized as Mean ± SD (Fig.1). Groups were compared by two factor analysis of variance (ANOVA) and the significance of mean difference within and between the groups was done by Newman-Keuls post hoc test. A two-tailed (α=2) probability (p) values less than $p<0.05$ were considered to be statistically significant. Analysis was performed on SPSS (version 13.0).

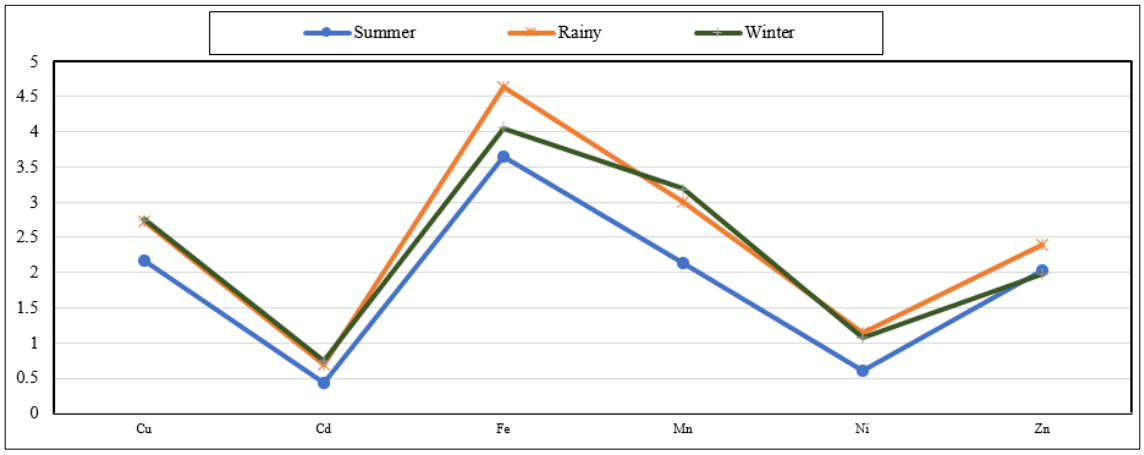


**Fig 1:** Graph analysis of averrage seasonal variation of heavy metals ($mg^{-l}$) in Diya Pipar ghat Son river.

**Copper (Cu):** During summer maximum amount of copper concentration was found in station B (2.36±0.22 $mg^{-l}$) followed by site C (2.21±0.36 $mg^{-l}$), site D (2.12±0.20 $mg^{-l}$) and site A (2.01±0.82 $mg^{-l}$), however the change was not statistically significant ($p>0.05$). In rainy season site C recorded maximum value followed by site D, site B and site A (Table 1). However, during winters, the concentration was found maximum in site B (3.16±0.25 $mg^{-l}$) and minimum in site A (2.28±0.44 $mg^{-l}$).

**Table 1:** Seasonal variation (Mean ± SD, n=3) of copper ($mg^{-l}$) in four selected site (A, B, C, D)

| Seasons | Site A | Site B | Site C | Site D |
|---|---|---|---|---|
| Summer | 2.01±0.82 | 2.36±0.22 | 2.21±0.36 | 2.12±0.20 |
| Rainy | 2.39±0.45 | 2.62±0.27 | 3.01±0.21 | 2.91±0.33 |
| Winter | 2.28±0.44 | 3.16±0.25 | 2.86±0.34 | 2.71±0.31 |

Seasonal variation in copper (between various site and between seasons)- not significant ($p>0.05$).

**Cadmium (Cd):** In summer the cadmium concentration was found maximum in river site B (0.82±0.24 $mg^{-l}$) which is significant than site A (0.44±0.28$mg^{-l}$) and also site C (0.36±0.20 $mg^{-l}$) and site D (0.11±0.12 $mg^{-l}$) recorded significant change in comparison with site B. It was observed that in rainy season site A recorded significantly higher concentration than in summer which also decreased significantly in winter. Beside in winters site D detected highly significant variation when compared with sites A, B, and C (Table 2).

**Table 2:** Seasonal variation (Mean ± SD, n=3) of cadmium ($mg^{-l}$) in four selected sites.

| Seasons | Site A | Site B | Site C | Site D |
|---|---|---|---|---|
| Summer | 0.44±0.28 | 0.82±0.24A | 0.36±0.20B | 0.11±0.12B |
| Rainy | S0.88±0.24 | 1.12±0.10 | 0.62±0.08B | 0.16±0.19ABC |
| Winter | S0.93±0.27 | 1.02±0.16 | S0.88±0.21 | 0.12±0.11ABC |

$^{A}p<0.05$ or $Ap<0.01$ in comparison with site 'A'; $^{B}p<0.05$ or $Ap<0.01$ in comparison with site 'B'

$^{B}p<0.05$ or $Ap<0.01$ in comparison with site 'B'; $^{C}p<0.05$ or $Ap<0.01$ in comparison with site 'C'

$^{S}p<0.05$ or $Ap<0.01$ in comparison with season "Summer"; $^{R}p<0.05$ or $Ap<0.01$ in comparison with season "Rainy"

**Iron (Fe):** It was recorded that in summer season site C (4.01±0.54 mg$^{-l}$) showed maximum value followed by site B (3.93±0.32 mg $^{-l}$), site D (3.85±1.07 mg$^{-l}$) and site A (2.78±1.15 mg$^{-l}$). But in rainy season maximum amount of iron was found in site B and minimum in Site D. During winters site C recorded maximum value followed by sites B, A and D (Table 3).

**Table 3:** Seasonal variation (Mean ± SD, n=3) of iron (mg - l) in four selected sites.

| Seasons | Site A | Site B | Site C | Site d |
|---|---|---|---|---|
| Summer | 2.78±1.15 | 3.93±0.32 | 4.01±0.54 | 3.85±1.07 |
| Rainy | 4.55±0.72 | 4.96±1.11 | 4.71±0.51 | 4.33±1.12 |
| Winter | 3.54±0.67 | 4.17±1.08 | 5.05±1.02 | 3.46±0.73 |

Seasonal variation in Iron (between sites and between seasons)- not significant ($p$>0.05).

**Manganese (Mn):** The manganese concentration was found maximum in site B (2.56±0.22 mg$^{-l}$) and site D (1.54±0.53 mg$^{-l}$) recorded lowest concentration in summer. Similar trend was observed in rainy season. But in winter it was found that site C (4.52±0.62 mg$^{-l}$) showed significantly higher concentration than site A and B and also in comparison with summer and rainy. Besides site D (2.73±0.54 mg$^{-l}$) recorded significantly lower value than others during winter season (Table 4).

**Table 4:** Seasonal variation (Mean ± SD, n=3) of manganese (mg$^{-l}$) in four selected sites.

| Seasons | Site A | Site B | Site C | Site d |
|---|---|---|---|---|
| Summer | 2.32±0.20 | 2.56±0.22 | 2.09±0.29 | 1.54±0.53 |
| Rainy | 3.03±0.45 | 3.39±0.29 | 2.97±0.48 | 2.66±0.67 |
| Winter | 2.59±0.49 | 2.91±0.66 | SR4.52±0.62AC | 2.73±0.54E |

$^{A}p$<0.05 or A$p$<0.01 in comparison with site 'A'; $^{B}p$<0.05 or A$p$<0.01 in comparison with site 'B'
$^{C}p$<0.05 or A$p$<0.01 in comparison with site 'C'; $^{D}p$<0.05 or A$p$<0.01 in comparison with site 'D'
$^{S}p$<0.05 or A$p$<0.01 in comparison with season "Summer"; $^{R}p$<0.05 or A$p$<0.01 in comparison with season "Rainy"

**Nickel (Ni):** During summer site B (0.97±0.28 mg$^{-l}$) recorded maximum value followed by sites C, A and D. It was observed that the site D (0.23±0.14 mg$^{-l}$) showed significantly lower concentration in comparison with site C. However, in rainy season maximum amount of nickel was recorded in site C (1.75±0.26 mg$^{-l}$), which is significantly higher than in summer. Same trend was observed in site A. Besides site D (0.23±0.16 mg$^{-l}$) recorded significantly lower concentration when compared with sites A, B, and C (Table 5).

**Table 5:** Seasonal variation (Mean ± SD, n=3) of nickel (mg$^{-l}$) in four selected sites

| Seasons | Site A | Site B | Site C | Site d |
|---|---|---|---|---|
| Summer | 0.59±0.50 | 0.97±0.28 | 0.63±0.25 | 0.23±0.14B |
| Rainy | S1.43±0.39 | 1.20±0.23 | S1.75±0.26 | 0.23±0.16ABC |
| Winter | 1.12±0.37 | 1.39±0.32 | S1.57±0.30 | 0.22±0.12ABC |

$^{A}p$<0.05 or A$p$<0.01 in comparison with site 'A'; $^{B}p$<0.05 or A$p$<0.01 in comparison with site 'B'
$^{C}p$<0.05 or A$p$<0.01 in comparison with site 'C'; $^{D}p$<0.05 or A$p$<0.01 in comparison with site 'D'
$^{S}p$<0.05 or A$p$<0.01 in comparison with season "Summer"; $^{R}p$<0.05 or A$p$<0.01 in comparison with season "Rainy"

**Zinc (Zn):** The maximum amount of zinc in summer was recorded in site A (3.22±0.25 mg$^{-l}$) followed by site B (2.86±0.29 mg$^{-l}$), site D (1.45±0.46 mg$^{-l}$) and site C (0.61±0.78 mg$^{-l}$). It was found that site D showed significantly lower concentration of zinc than site B in summer season. In rainy season site A and C recorded significantly higher concentration than in summer. Further, site D recorded significantly lower concentration in comparison with sites A, B, and C. During winter season site C (1.68±0.44 mg$^{-l}$) recorded significantly lower concentration than in summer and also the sies D (1.31±0.16 mg$^{-l}$) showed significantly lower value when compared with other three site (Table 6).

**Table 6:** Seasonal variation (Mean ± SD, n=3) of zinc (mg$^{-l}$) in four selected sites

| Seasons | Site A | Site B | Site C | Site d |
|---|---|---|---|---|
| Summer | 3.22±0.25 | 2.86±0.29 | 0.61±0.78 | 1.45±0.46A |
| Rainy | 2.56±0.72 | 3.30±0.40 | 1.33±0.51 | 2.40±0.26 |
| Winter | 2.42±0.81 | 2.50±0.52 | 1.68±0.44 | 1.31±0.16 |

$^{A}p$<0.05 or A$p$<0.01 in comparison with site 'A'; $^{B}p$<0.05 or A$p$<0.01 in comparison with site 'B'
$^{C}p$<0.05 or A$p$<0.01 in comparison with site 'C'; $^{D}p$<0.05 or A$p$<0.01 in comparison with site 'D'
$^{S}p$<0.05 or A$p$<0.01 in comparison with season "Summer"; $^{R}p$<0.05 or A$p$<0.01 in comparison with season "Rainy"

Throughout the duration of the study, a notable fluctuation in the levels of copper content was observed across three distinct seasons at all designated locations. Remarkably, the highest concentration was detected specifically at site B, but solely during the rainy season. The chronic level of Cu is 0.02-0.2 mg$^{-l}$ (Moore, 1984)[16]. When the rate at which organisms absorb copper surpasses their ability to excrete it, the element becomes toxic. As both plants and animals have a propensity to accumulate copper, it becomes imperative to minimize its presence in waterways. Bordoloi *et al.* (2002) [17] had reported that metals deposited in the sediments come out during heavy rainfall and flow into the water system. In a study conducted by Roberto *et al.* (2008) [18], it was discovered that precipitation has the ability to permeate the soil and underlying geological structures, thereby dissolving metals such as iron (Fe) and allowing them to seep into aquifers and subsequently into the water system, ultimately leading to elevated concentrations. Notably, iron (Fe), copper (Cu), and zinc (Zn) comprise a significant proportion of the waste and effluents discharged from paper mills, which are subsequently transported to rivers during rainy periods, consequently resulting in heightened concentrations of these metals during the rainy season. Shivkumar and Biksham (1995) [19] conducted a meticulous analysis of the presence of copper in industrial effluents, surface water, and subsurface groundwater. Astonishingly, their findings revealed that the concentration of copper exceeded the permissible limits by a staggering five to tenfold.

The presence of excessive levels of cadmium, exceeding the acceptable standards, was observed in all four stations and varied significantly throughout the seasons. The highest concentration was recorded during the rainy season at site B. Cadmium enters surface waters through various means such as paints, pigments, glass enamel, and the deterioration of galvanized pipes. Additionally, the use of studded tires has been identified as a source of cadmium deposition on road surfaces. While there have been a few documented cases of

cadmium poisoning in humans due to consuming contaminated fish, it is worth noting that cadmium is less harmful to plants compared to copper, but poses a similar level of toxicity as lead and chromium. It is equally toxic to invertebrates and fishes (Moore, 1984) [32]. Setia *et al.* (1998) [20] concluded that sewage water contain 4 to 10 times more Cd content than tube well water.

In this comprehensive analysis, it has been determined that the iron concentration in all four locations exceeds the prescribed threshold for water quality standards. Remarkably, throughout the year, this concentration exhibits a gradual escalation from the summer to winter months, yet the fluctuations lack statistical significance. Gobler and Cosper (1996) [21] and several Indian workers (Munnawar, 1970; Choudhury *et al.*, 1998; Khan and Bhat, 2000) [22-24], have recorded much higher concentration of iron in lake and pond waters. In their remarkable study, Reemtsma *et al.* (2000) [25] unveiled the astonishingly high levels of iron concentration found in urban runoff originating from the discharge of municipal wastewater.

Manganese, while not inherently toxic, leaves behind stubborn and unsightly stains on household plumbing and laundry. This metal has been discovered in domestic wastewater, and its levels remain fairly constant throughout the summer and rainy seasons. However, during the winter months, a notable increase in manganese concentration was observed specifically in site C. This heightened presence of trace metals may stem from human activities such as waste incineration, vehicular emissions, fuel consumption, and the use of fertilizers (Councell *et al.*, 2004) [26], which likely come from the upper basin of the lotic systems that flow into the wetland.

The accumulation of nickel in organisms, especially in phytoplankton and other aquatic plants, serves as a valuable indicator of water pollution. Various mechanisms, such as precipitation, complexation, and adsorption on clay particles, as well as uptake by organisms, facilitate its deposition in sediment (Barałk *et al.*, 1999) [27]. Nickel and its compounds possess a multitude of industrial and commercial applications, and as the wheels of industrialization turn, their release into ecosystems has surged. In the course of our current inquiry, we have observed that the concentration of nickel reaches its zenith during the rainy season in station C, a finding of immense import when juxtaposed with the summer readings from the very same stations. Furthermore, station D has demonstrated a noticeably diminished presence of this metal during summer, in stark contrast to its abundance in both the rainy and winter seasons.

Throughout the three seasons, zinc was discovered at all of the locations, exhibiting minimal noteworthy fluctuations. Nevertheless, during the summertime, site D exhibited a notably lower concentration compared to the rainy and winter seasons. Additionally, higher concentrations were observed during the winter season at stations B and C. It is worth noting that zinc plays a crucial role in nucleic acid synthesis and actively engages in an array of metabolic processes involving carbohydrates, lipids, proteins, and nucleic acid (Mc. Dowell, 1992) [28], it can be toxic also when present in excess amount as changes in blood parameters and tissue structures have been reported on exposure to zinc (Gupta and Chakraborty, 1995; Banerjee, 1998 and Gujare and Bhatia, 2023) [29-31].

## Conclusion

The findings of the study indicate that the water quality of the Son river at Diyapipar is contaminated, surpassing the acceptable thresholds. The discharge from mills, agricultural and urban runoff, and the continual disposal of waste materials, particularly sanitary waste, have detrimental effects on the water quality of this body. A better understanding of this issue is crucial for effective management. Among the available technologies for treating polluted soil and water, phytoremediation utilizing aquatic plants shows promise due to its cost-effectiveness in comparison to traditional physical or chemical methods. Additionally, it has fewer adverse impacts and is suitable for eliminating low concentration pollutants on a large scale, which represents the subsequent phase of our investigation.

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