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# Assessment of heavy metal pollution of Yamuna water in Mathura region through index analysis approach

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**Abstract**
Heavy metal pollution of Yamuna river water in Mathura region at sites viz., M1, M2, M3, M4 and M5 was assessed for summer. Mean concentration followed the order Zn (1860 $\mu gl^{-1}$)> Fe (1222 $\mu gl^{-1}$)> Pb (656 $\mu gl^{-1}$)> Cd (254 $\mu gl^{-1}$)≥ Mn (158 $\mu gl^{-1}$)> Cu (116 $\mu gl^{-1}$)> Ni (96 $\mu gl^{-1}$)> Cr (70 $\mu gl^{-1}$). Fe, Pb, Ni and Cr were within permissible limit for irrigation water quality at all sites whereas Cd, Zn, Cu and Mn were above the limits at specific sites. Mean heavy metal pollution index (HPI) for each sampling site reflected highest pollution at M4 site. Mean HPI for Yamuna water in summer, i.e., 2035, was conspicuously higher than the maximum limit of 100. Metal quality index (MQI) value was highest at M4 site i.e., 75 and mean MQI of the river was 30. Pearson's analysis showed significant positive correlation among all heavy metals indicating common point-source of pollution.

**Keywords:** Heavy metal pollution index (HPI), Heavy metals, Metal quality index (MQI), Pearson's correlation, Yamuna

## 1. Introduction
Owing to rapid urbanization and industrialization in burgeoning cities, surface and groundwater qualities has deteriorated which critically affects agriculture, animal and human health worldwide including Indian subcontinent (Paul 2017; Kumar *et al.*, 2017) [18, 11]. Indian agriculture full fills its water demand mostly from surface sources like river, reservoir, dam etc. However, Indian rivers are getting polluted and contaminated on receiving the huge quantity of untreated wastewater being discharged from urban and industrial sources (CPCB, 2012) [7]. The contamination of rivers by heavy metals is a serious ecological problem and needs to be monitored regularly as heavy metals are toxic due to their non-degradable nature and bio-accumulation through food chain. In many parts of the world water of polluted rivers is being used for irrigation in agriculture without assessing its suitability leading to deterioration in the quality of soil as well as crop (Furhan *et al.*,, 2004; Gholami and Srikantaswamy, 2009) [8, 9]. Heavy metal pollution index is a helpful tool in identifying and quantifying trends in water quality with respect to spatial variation in concentration of heavy metals. The metal quality index is computed to assess the suitability of water resources for drinking/irrigation purpose with respect to metals (Ojekunle *et al.*, 2016) [17]. Pearson's correlation analysis is an effective tool for identification of pollution sources (Yalcin *et al.*, 2010, Manoj *et al.*, 2012) [20, 13].
Yamuna is the main freshwater resource in Mathura district (Uttar Pradesh) required for meeting domestic, industrial and irrigation water demands. The catchment area of Yamuna in Mathura is highly urbanized and is networked by several drains. The heavy metal content in river Yamuna has been monitored several times by various water resource development authorities (Kaur and Mehra, 2012; Malik *et al.*, 2014) [10, 12]. However, in present study first time an attempt has been made to evaluate water quality of Yamuna's stretch in Mathura with respect to heavy metals (Fe, Pb, Cd, Cr, Cu, Ni and Mn) using indices i.e., heavy metal pollution index (HPI), metal quality index (MQI) (Abdel-Satar *et al.*, 2017) [1] and Pearson's correlation analysis, for its suitability in irrigation.

## 2. Material and methods

**Sampling sites:** A total of five sampling sites were selected along the stretch of Yamuna river in Mathura district i.e., M1, M2, M3, M4 and M5 (Fig. 1). Sites M2, M3 and M4 were lying inside the municipality zone of Mathura, whereas, M1 and M5 sites were lying outside themunicipality zone and 5 Km upstream and downstream of the municipality area boundary, respectively.

**Analysis of heavy metals:** Water samples were collected from river at all five sites during summer (May 2016). The samples collected from each site consisted of 3 composite samples taken from 1 foot below the water surface using pre-sterilized 500 ml HDPE bottles to avoid unpredictable changes in characteristics. Water samples collected were placed at 4 °C in an ice-jacket and transported to the laboratory immediately for further analysis. The collected samples were acidified with concentrated nitric acid to a pH below 2.0 to minimize precipitation and adsorption on bottles walls as required by the standard procedure. The concentrations of heavy metals were determined using an atomic absorption spectrometry (Perkin-Elmer, 3300/96, MHS-10) after acid-digestion procedure for heavy metals analysis as per APHA (2012) [3]. All analyses were carried out in triplicate, and the results were expressed as the mean.

The overall quality of river water with respect to content of heavy metals is assessed by HPI values. The critical HPI value is 100. The weighted arithmetic average of the concentrations was used to calculate HPI values using the Eq. 1 given by Mohan *et al.* (1996) [16]

$$HPI = \frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi} \quad (1)$$

where Wi is the unit weightage defined as reciprocal value of Si where Si is the maximum permissible limit for irrigation water given by FAO (Ayers and Westcot, 1994), and n is the number of parameters considered. Qi is the sub-index of i-th parameter, and calculated by Eq. 2

$$Qi = \sum_{i=1}^{n} \frac{Mi}{Si} \times 100 \quad (2)$$

Where Mi is the monitored value of heavy metal, Si is the standard value of i-th parameter, in ppm (µg/L).

The higher the concentration of a metal compared to its respective maximum permissible limit (Si), the worse the quality of the water. MQI value >1 is a threshold of warning (Bakan *et al.*, 2010) [6]. According to (Tamasi and Cini, 2004) [19], the MQI is calculated by Eq. 3

$$MQI = \sum_{i=1}^{n} Mi/Si \quad (3)$$

The data were statistically analyzed using the SPSS 20.0 statistical software package to calculate average, standard deviation, Pearson's correlation coefficient and level of significance. Level of significance was calculated at $p < 0.05$.

## 3. Results and discussion

The concentrations of eight heavy metals analysed for summer and some basic statistics are shown in Table 1. The mean concentration of heavy metals in Yamuna water followed the order Zn (1860 $\mu g l^{-1}$)> Fe (1222 $\mu g l^{-1}$)> Pb (656 $\mu g l^{-1}$)> Cd (254 $\mu g l^{-1}$)≥ Mn (158 $\mu g l^{-1}$)> Cu (116 $\mu g l^{-1}$)> Ni (96 $\mu g l^{-1}$)> Cr (70 $\mu g l^{-1}$). The concentrations of all heavy metals increased continuously from M1 to M4 sites but decreased considerably at M5 which may be due to the fact that M5 site being located 5 Km downstream of municipality boundary of the city, therefore, the distance provided sufficient time for heavy metals to settle down from dissolved phase to the bed sediments of river due to precipitation and sorption (Abdel-Ghani and Elchaghaby, 2007) [2]. The concentration of all heavy metals were highest at M4 site because it is positioned downstream of all the municipal drains of Mathura which carry waste discharged from most of the fertilizer and chemical industries and residential areas of the city. Heavy metals viz., Fe, Pb, Ni and Cr were found within maximum permissible limits for irrigation water quality at all sites. Whereas other heavy metals were above maximum permissible limits for irrigation water quality i.e., Cd at all sites, Zn at M3 and M4, Cu & Mn at M4. Cd concentration was found 3 to 68 times higher than maximum permissible limit for irrigation water quality at different sites. Its source was wastewater discharged from painting and electroplating industries located in the city. Zn was found 1.05 to 1.2 times higher than maximum permissible limit for irrigation water quality at M3 and M4 sites which can be accounted due to municipal and fertilizer industries wastewater. Cu and Mn were found 1.17 and 1.25 times higher than maximum permissible limit for irrigation water quality at M4 site.

**Table 1:** Heavy metal concentrations in river water at different sampling sites and statistical values for mean concentration of various heavy metals.

| Heavy metals | Concentration (µg/l) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **M1** | **M2** | **M3** | **M4** | **M5** | **Mean** | **SD** |
| Fe | 460 | 670 | 1890 | 2580 | 510 | 1222 | 959 |
| Pb | 320 | 450 | 670 | 1120 | 720 | 656 | 306 |
| Cd | 30 | 50 | 460 | 680 | 50 | 254 | 298 |
| Zn | 1700 | 1900 | 2100 | 2400 | 1200 | 1860 | 450 |
| Cr | 40 | 50 | 80 | 120 | 60 | 70 | 31 |
| Cu | 50 | 75 | 130 | 235 | 90 | 116 | 72 |
| Ni | 85 | 95 | 110 | 115 | 75 | 96 | 16 |
| Mn | 80 | 160 | 180 | 250 | 120 | 158 | 64 |

The HPI values were determined using mean concentrations of eight heavy metals (Fe, Pb, Cd, Zn, Cr, Cu, Ni and Mn). Table 2 provides details of calculating HPI, Wi and Qi values for all sites. The critical value of the heavy metals pollution index is 100 (Milivojević, 2016) [14]. The mean HPI for Yamuna in Matura for summer was found very high i.e, 2035 indicating high heavy metal pollution. The high HPI values were mainly due to industrial and domestic wastewater discharge into river.

**Table 2:** Heavy metal Pollution Index (HPI) calculations for river water based on mean heavy metal concentration in summer

| HM | Mi | Si | Wi (1/Si) | Qi (Mi/Si * 100) | Wi*Qi |
|---|---|---|---|---|---|
| Fe | 1222 | 5000 | 0.0002 | 24.44 | 0.004888 |
| Pb | 656 | 5000 | 0.0002 | 13.12 | 0.002624 |
| Cd | 254 | 10 | 0.1 | 2540 | 254 |
| Zn | 1860 | 2000 | 0.0005 | 93 | 0.0465 |
| Cr | 70 | 100 | 0.01 | 70 | 0.7 |
| Cu | 232 | 200 | 0.005 | 116 | 0.58 |
| Ni | 192 | 200 | 0.005 | 96 | 0.48 |
| Mn | 158 | 200 | 0.005 | 79 | 0.395 |

ΣWi = 0.1259, ΣWi*Qi = 256, HPI = 2035

HPI of different sampling sites were compared to assess pollution load and assess the water quality for the selected sites (Table 3). HPI values were much higher than critical limit at all sites. Also, from the values of mean HPI for each sampling site could be concluded that the pollution load at sampling site M4 was most significant (i.e., 5430).

**Table 3:** Heavy metal Pollution Index (HPI) calculations for river water at each sampling site in summer

| Sampling site | HPI of each site |
|---|---|
| M1 | 248 |
| M2 | 411 |
| M3 | 3673 |
| M4 | 5430 |
| M5 | 411 |
| Mean HPI | 2035 |

Metal quality index was used to estimate total metal pollution of Yamuna water for irrigation use by computing all measured metals (Table 4). All sites along the studied stretch were seriously threatened with metal pollution for irrigation (MQI > 1), MQI reached to 75 at site M4.

**Table 4:** Metal Quality Index (MQI) calculations for river water at each sampling site in summer

| Sampling site | MQI of each site |
|---|---|
| M1 | 6.15 |
| M2 | 9.17 |
| M3 | 51.66 |
| M4 | 75.89 |
| M5 | 8.69 |
| Mean MQI | 30.31 |

The Pearson correlation analysis for heavy metal content in Yamuna water revealed that there were significant strong positive correlations ($p < 0.05$) between all the eight heavy metals (Table 5). Positive correlation between metals analysed at different sites showed either an association/interaction between the metals or similar sources of input (Miller and Miller, 2002) [15]. Strong correlation between two heavy metals indicates strong dependence of both metals on the same causal factor (Ashraf *et al.*, 2012) [4].

**Table 5:** Pearson's correlation analysis of heavy metal concentrations at various sampling sites in river water

| Heavy metals | Pearson's correlation (r) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Fe | Pb | Cd | Zn | Cr | Cu | Ni | Mn |
| Fe | 1 | 0.82009379 | 0.997851 | 0.846259 | 0.952458 | 0.941961 | 0.919295948 | 0.913398986 |
| Pb | | 1 | 0.8327 | 0.466148 | 0.952856 | 0.949263 | 0.919295948 | 0.913398986 |
| Cd | | | 1 | 0.820199 | 0.957525 | 0.945392 | 0.896277751 | 0.893175566 |
| Zn | | | | 1 | 0.701862 | 0.716357 | 0.968268549 | 0.800487157 |
| Cr | | | | | 1 | 0.996687 | 0.779551726 | 0.923746198 |
| Cu | | | | | | 1 | 0.776068527 | 0.928936861 |
| Ni | | | | | | | 1 | 0.863547626 |
| Mn | | | | | | | | 1 |

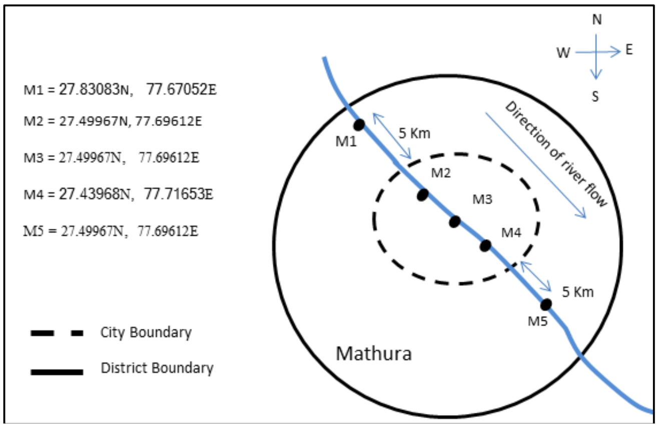


**Fig 1:** Schematic representation of five sampling sites along Yamuna river stretch in Mathura

## 4. Conclusion

Our study on river Yamuna for Mathura stretch revealed that site M4 is highly polluted with heavy metals. HPI of river shows that Yamuna is critically polluted with heavy metals and unsafe for irrigation in summer. MQI was much higher than critical limit (i.e., MQI> 1) at all sites indicating severe total metal pollution. Pearson's correlation analysis showed that all heavy metals had common point source of pollution. The study will be useful in designing policies and action plans to concerned water resource management authorities for pollution abatement and restoration of the river Yamuna.

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