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Assessment of heavy metal and organic pollution in Yamuna river at Etawah district of Uttar Pradesh

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Abstract
Rapid urbanization and industrialization has led to discharge of enormous quantity of heavy metals laden wastewater which has destroyed rivers ecosystems. The objective of study was to assess heavy metal and organic pollution of Yamuna river water vis a vis irrigation water quality standards in Etawah district of Uttar Pradesh. Four sampling sites *viz.,* E1, E2, E3 and E4 were selected along Yamuna stretch in Etawah district and samples were collected in summer and post-rainy seasons during 2016. Six heavy metals (i.e., Pb, Cd, Fe, Cu, Cr and Zn), dissolved oxygen (DO) and biochemical oxygen demand (BOD) of river water were analysed. Heavy metal pollution index (HPI) was used to determine severity of heavy metal pollution in the river. The mean concentration of heavy metals followed the order of Fe> Pb> Zn> Cd> Cr> Cu in summer and Fe> Zn> Cr> Pb> Cd> Cu in post-rainy season. Pb, Fe, Zn and Cu were present within permissible limits as per irrigation water quality standards in both the seasons. The concentrations of Pb, Cd, Cr and Cu decreased by 82%, 73%, 34% and 76%, respectively, whereas that of Fe and Zn increased by 29% and 48%, respectively, during post-rainy season. Heavy metal pollution index (HPI) of each sampling site revealed highest pollution at E2 site. Mean HPI for Yamuna water in summer i.e., 1534 decreased to 412 in post-rainy season. The overall HPI of river water was recorded 973 which is much higher than critical limit of 100. In both the seasons, DO remained almost consistent at all the sampling sites but BOD decreased conspicuously at E2 and E3 sites.

Keywords: Biochemical oxygen demand (BOD), Dissolved oxygen (DO), Heavy metal pollution index (HPI), Yamuna river, Etawah

Introduction
Water is the most important input for agriculture, hydro-electric power, municipal water supply, fishing, recreation and domestic activities. Discharge of a consortium of municipal, industrial and domestic wastewater, which contains mixture of different contaminants, contributes to water pollution of aquatic ecosystems specially rivers (Mahre *et al.*, 2007; Zhao *et al*., 2015) [11, 21]. Pollutants include heavy metals, oxygen demanding wastes, inorganic acids etc. but they pose deleterious effects on aquatic organisms (Ahmed *et al.*, 2015; Kpee and Nwineewii, 2017) [10]. Heavy metals are abundantly present in lithosphere and often find their way into the environment through volcanism, weathering of rocks, soil erosion etc., but largely via industrial effluent discharge (Obaroh *et al*., 2015) [15]. Some heavy metals are essential and required by organisms in traces such as cobalt, copper, iron, manganese, molybdenum, vanadium, strontium and zinc (Jaishankar *et al.*, 2014) [6]. However, non-essential heavy metals such as cadmium, chromium, mercury, lead, arsenic and antimony are toxic even if present in traces (Paul, 2012). Heavy metals are toxic due to their non-degradable property and bio-accumulation behavior via food chain (Obaroh *et al.*, 2012; Gupta *et. al*., 2013) [16, 7]. Dissolved Oxygen (DO) is the amount of oxygen dissolved in water and is a measure of the degree of pollution by organic matter**.** Biochemical Oxygen Demand (BOD) is a measure of oxygen that would be needed by the microorganism to decompose the organic and inorganic pollutants in polluted water. Sewage present in municipal wastewater contains large amount of organic material that is largely oxidized by microorganisms but it leads to oxygen deficit for variable time periods in river and creates anoxic condition killing aquatic life forms (Yadav *et al*., 2003; Prajapati and Dwivedi, 2016) [20, 18]. Seasonal monitoring of heavy metal concentration, DO and BOD in rivers is of utmost importance under the current scenario of water crisis in order to make more stringent standards for controlling pollution of rivers so that it can be suitable for agriculture, animal and human consumption.

Yamuna river receives untreated/partially treated wastewater discharged through network of municipality drains in various districts. Earlier studies have also assessed heavy metal and organic pollution level of river Yamuna in Delhi, Mathura and Agra districts (Kaur and Mehra, 2012; Malik *et al*., 2014) [9, 12]. In this study an attempt was made to evaluate heavy metal and organic pollution *vis a vis* irrigation water quality standards in Etawah district of Uttar Pradesh through heavy metal pollution index (HPI) and measurement of DO and BOD in river water.

Materials and methods

Sampling sites: After field survey by multidisciplinary team, total four sampling sites were selected along the stretch of Yamuna river in Etawah district i.e., E1, E2, E3 and E4 (Fig. 1). Sites E1and E4 were lying outside the municipality zone of Etawah, whereas, E2 and E3 sites were lying inside the municipality zone. E2 site was located near sewage entry into river, and E3 site was located at 5 Km upstream from E2.

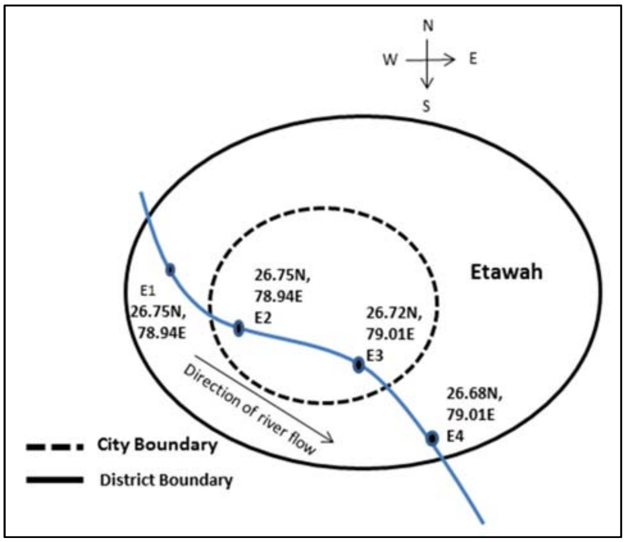

Fig 1: Schematic representation of four sampling sites along Yamuna river stretch in Etawah district of Uttar Pradesh.

Heavy metal analysis: Water samples were collected in May and October, 2016 at 1 foot depth from the water surface in pre-sterilized 500 ml HDPE bottles at each site and brought to the laboratory in an ice-jacket. Water samples collected were acidified by adding 1.0 M of concentration HNO_3 to minimize heavy metals precipitation and adsorption on bottles walls and stored in refrigerator for further analysis. Concentrations of six heavy metals (Pb, Cd, Fe, Cr, Cu and Zn) in river water samples were determined using AAS after acid-digestion of water samples as per APHA (2012) [2].

BOD and DO analysis: Water samples collected in 300 ml BOD bottles were analysed for DO and BOD through Winkler's Iodometric titration method as reported by APHA (2012) [2].

Calculation of Heavy metal pollution index (HPI)

The severity heavy metal pollution with respect to irrigation water quality standard was assessed by HPI values. The maximum permissible HPI value is 100. HPI of river Yamuna was calculated by using Eq. 1 (Mohan *et al.* 1996) [14]:

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

Where, Wi is the sum of 1/Si values of different heavy metals. Si is the maximum permissible limit of heavy metals (µg/L) for irrigation water given by FAO (Ayers and Westcot, 1994). n is the number of parameters considered.
Qi is the sub-index of i-th parameter, and calculated by Eq. 2

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

Where, Mi is the monitored concentration of heavy metal (µg/L).

Results and Discussion

The seasonal variations in concentrations of six heavy metals (Pd, Cd, Fe, Cr, Cu and Zn) estimated at four sampling sites along river Yamuna, Etawah is depicted in Table 1 and Fig. 2. The mean concentration of heavy metals analyzed in the river water samples showed the order of Fe (1237.25 µg/l) > Pb (356 µg/l)> Zn (316.75 µg/l)> Cd (176.25 µg/l)> Cr (139.25 µg/l)> Cu (72.50 µg/l) in summer and Fe (1600 µg/l)> Zn (468.5 µg/l) > Cr (92 µg/l)> Pb (63.75 µg/l)> Cd (46.75 µg/l)> Cu(17.25 µg/l) in post-rainy season. Pb, Fe, Zn and Cu were present within permissible limits as per irrigation water quality standards, whereas, Cd and Cr were above critical limits during both the seasons except at E1 site during post-rainy season. Cd was 6 to 32 times higher than permissible limit in summer and 1.3 to 9 times in post-rainy season. Similarly, Cr was 1.87 to 2.2 times higher than maximum permissible limit in summer and 1.1 to 1.45 times higher in post-rainy season. All the heavy metals had highest concentrations at E2 site in both the seasons as it is present downstream of the sewage entry into river. Whereas, at E3 and E4 sites concentration of heavy metals decreased which can be explained due to the fact that while transportation heavy metals form organo-metallic complexes and precipitates as hydroxides which settle down at bottom of river (Abdel-Ghani and Elchaghaby, 2007) [1]. The mean concentration of Pb, Cd, Cr and Cu decreased during post–rainy season by 82%, 73%, 34% and 76%, respectively, due to dilution effect. Contrarily, mean concentration of Fe and Zn increased by 29% and 48%, respectively, which could be due to desorption of these metals from sediments after dilution. Heavy metals after released into river water may get adsorbed on sediment particles as inorganic complexes or hydrated ions which constitute the labile fraction (Vukovic *et al*., 2014) [19]. The increase in mean concentration of Fe and Zn in post-rainy season was inversely proportional to their covalent index i.e., 2.16 and 2.01, respectively. Higher covalent index of a heavy metal indicates its stronger adsorption and hence lower desorption due to dilution (Pal and Rai, 2009) [17]. Desorption of other heavy metals (Pb, Cd, Cr and Cu) also would had occurred but, since dilution factor being prominent, therefore, net decrease in concentration was observed.

Table 1: Seasonal concentration of heavy metals in Yamuna river water at different sampling sites.

Heavy metals	Summer						Post-rainy season					
	Concentration (µg/l)				Mean	SD*	Concentration (µg/l)				Mean	SD*
	E1	E2	E3	E4			E1	E2	E3	E4		
Pb	128	621	544	131	356	263.42	12	108	90	45	63.75	43.5
Cd	60	321	201	123	176.25	112.42	8	90	76	13	46.75	42.29559
Fe	980	1902	1200	867	1237.25	464.23	1234	2323	1609	1234	1600	513.3946
Cr	50	220	187	100	139.25	78.12	34	145	111	78	92	47.36384
Cu	67	112	81	30	72.5	34	4	30	23	12	17.25	11.52895
Zn	230	460	321	256	316.75	11.53	290	460	321	256	468.5	174.9848

*Standard deviation

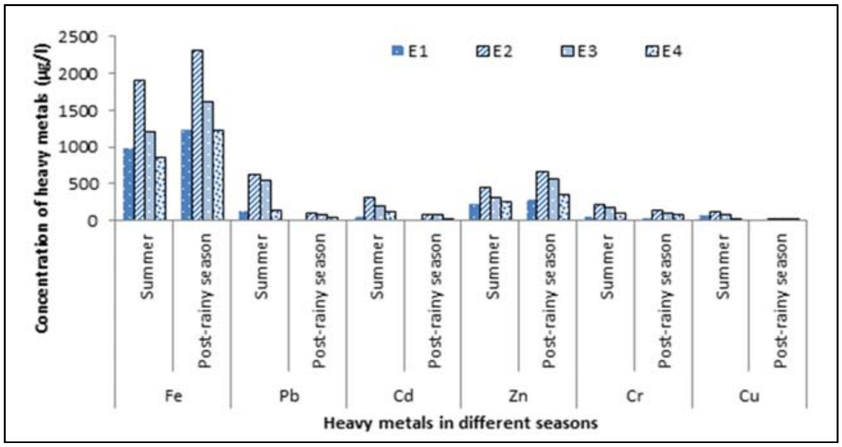

Fig 2: Seasonal variation in heavy metals concentration of Yamuna river water at Etawah District.

Table 2 represents calculation of HPI for both summer and post-rainy seasons. The mean HPI values for river water in Etawah district during summer (1534) and post-rainy seasons (412) were much higher than the critical limit (Milivojević, 2016) [13]. The overall HPI of Yamuna was 973, again above critical limit, indicating high domestic and industrial wastewater discharge into river. HPI of different sampling sites during both seasons were compared to assess heavy metal pollution load at sampling sites (Table 3). HPI values were above the critical index limit at all sites in summer, whereas only at E1 site was below critical index limit during post-rainy season. HPI of river at E2 site was highest in both the seasons (2772 in summer and 790 in post-rainy season) followed by other sites in the order of E3>E4>E1.

Table 2: Heavy metal Pollution Index (HPI) of Yamuna river in summer and post-rainy seasons.

Heavy metals	Si	Wi (1/Si)	Summer			Post-rainy season		
			Mi	Qi (Mi/Si * 100)	Wi*Qi	Mi	Qi (Mi/Si * 100)	Wi*Qi
Pb	5000	0.0002	356	7.12	0.0014	63.75	1.275	0.00025
Cd	10	0.1	176.25	1762.5	176.25	46.75	467.5	46.75
Fe	5000	0.0002	1237.25	24.74	0.005	1600	32	0.0064
Cr	100	0.01	139.25	139.25	1.39	92	92	0.92
Cu	200	0.005	72.5	36.25	0.18	17.25	8.625	0.043
Zn	2000	0.0005	316.75	15.84	0.0079	468.5	23.425	0.012

ΣWi = 0.1159, ΣWi*Qi (summer) = 178, HPI (summer) = 1534
ΣWi*Qi (post-rainy) = 48, HPI (post-rainy season) = 412

Table 3: Heavy metal Pollution Index (HPI) of Yamuna river at each sampling site in summer and post-rainy seasons

Sampling site	HPI of each site	
	Summer	Post-rainy season
E1	519.22	72.15
E2	2772.2	790
E3	1770.64	665.99
E4	1070.62	119.27
HPI of river	1534	412
Mean HPI of river	973	

The seasonal variation in DO and BOD of river Yamuna at different sampling sites in Etawah district is shown in Fig. 3. The DO of river ranged between 5 to 6 mg/l and 5.8 to 9 mg/l during summer and post-rainy seasons, respectively, at different sampling sites which is good for aquatic life propagation as per surface water quality standards (IS: 2296). It increased slightly during post-rainy season at all sites due to dilution and increase in flow of river. Contrarily, BOD ranged between 10 to 30 mg/l which was substantially higher than permissible limit of 3 mg/l at all sites in summer which is required for survival of fishes and aquatic life in river as per IS: 2296, but lower than maximum critical limit (100 mg/l) of irrigation water quality standard. However, BOD decreased during post rainy season due to dilution effect and ranged between 2 to 23 mg/l. BOD is directly proportional to organic sewage pollution (Christopher *et al*., 2012), but it decreased conspicuously at E2 and E3 sites by 1/1.31 and 1/1.66, respectively in summer and 1/1.5 and 1/1.8, respectively, in post-rainy season, despite sewage entry at E2 site. It indicated that sewage entering into river near and upstream of E2 site diluted BOD of the river.

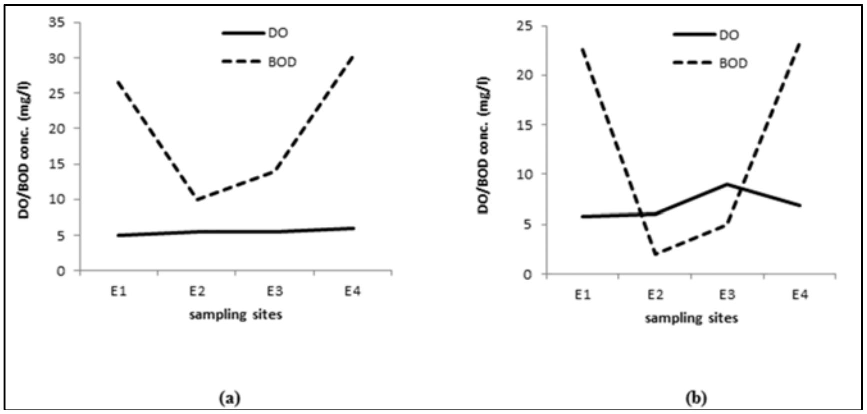

Fig 3: Seasonal variation in DO and BOD of Yamuna river in (a) summer (b) post-rainy seasons at different sampling sites in Etawah district.

Conclusion

The present study on heavy metal pollution of river Yamuna for Etawah stretch revealed that river water is highly polluted at E2 mainly due to discharge through municipality drains which should be carefully taken by environmentalist and planners. The study has relevance to water resource development and management authorities in designing policies and action plans for the restoration of Yamuna river ecosystem. The continuous monitoring of various pollutants in river Yamuna should be done to standardize and implement *in-situ* remediation technologies. The study will also provide farmers an idea on best way for its use in agriculture following desired dilution.

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References

1. Abdel-Ghani NT, Elchaghaby GA. Influence of operating conditions on the removal of Cu, Zn, Cd and Pb ions from wastewater by adsorption. Int. J. Environ. Sci. Technol. 2007; 4:451-456.
2. APHA. Standard Methods for examination of water and wastewater, 22nd edn. American Public Health Association, Washington, USA, 2012.
3. Ayers RS, Westcot DW. Water quality for agriculture. Irrigation and Drainage Paper' 29 Rev. 1. FAO, Rome. 1994, 174.
4. Christopher D, Kaur S, Singh R. Water quality status of river Yamuna in Delhi with reference to heavy metals: A Review. Int. J. Pharm. Med. & Bio. Sc., 2012; 1(2):266-271.
5. CPCB. Status of water quality in India. Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, Government of India, 2012.
6. Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN. Toxicity, mechanism and health effects of some heavy metals. Interdiscip. Toxicol. 2014; 7:60-72.
7. Gupta DK, Vandenhove H, Inouhe M. Role of Phytochelatins in Heavy Metal Stress and Detoxification Mechanisms in Plants. In: Gupta D., Corpas F., Palma J. (eds) Heavy Metal Stress in Plants. Springer, Berlin, Heidelberg. 2013.
8. ISI (Indian standards institution), Surface water quality standards, IS: 2296.
9. Kaur S, Mehra P. Assessment of heavy metals in summer and winter seasons in River Yamuna segment flowing through Delhi. Indian J. Environ. Ecol. 2012; 3:149-165.
10. Kpee F, Nwineewii JD. Heavy Metals Concentrations in Shellfish and Sediments of Andoni River, Rivers State, Nigeria. Chem. Sci. Rev. Lett. 2017; 6(22):1348-1355.
11. Mahre MY, Akan JC, Moses EA, Ogugbuaja VO. Pollution Indicators in River Kaduna, Kaduna State, Nigeria. Trends Appl. Sci. Res. 2007; 2:304-311.
12. Malik D, Singh S, Thakur J, Singh RK *et al.* Review article heavy metal pollution of the Yamuna River: an introspection. Int. J. Current Microbiol. Appl. Sci. 2014; 3:856-863.
13. Milivojević J, Krstić D, Šmit B, Djekić V. Assessment of Heavy Metal Contamination and Calculation of Its Pollution Index for Uglješnica River, Serbia. Bull. Environ. Contam. Toxicol. 2016; 97:737-742.
14. Mohan SV, Nithila P, Reddy SJ. Estimation of heavy metal in drinking water and development of heavy metal pollution index. J. Environ. Sci. Health A. 1996; 31:283-289.
15. Obaroh IO, Abubakar U, Haruna MA, Elinge MC. Evaluation of some heavy metals concentration in river Argungu. J. Fish. Aq. Sci., 2015; 10:581-586.
16. Obaroh IO, Elinge CM, Nwankwo C. Assessment of some heavy metals and physic-chemical parameters of Jega river, North Western Nigeria. Int. J. Nat. applied Sci. 2012; 8:78-81.
17. Pal R, Tewari S, Rai JPN. Metals sorption from aqueous solutions by Kluyveromyces marxianus: Process optimization, equilibrium modeling and chemical characterization. Biotechnol. J. 2009; 4:1471-1478.
18. Prajapati UB, Dwivedi AK. Free Oxygen Budget of a Polluted Tropical River. Hydrol. Current Res. 2016; 7:235.
19. Vukovic D, Stankovic SJ, Vukovic Z, Jankoviv K. Transport and storage of heavy metals in the Sava River Basin in Serbia. J. Serbian Chem. Soc. 2014; 79:379–387.
20. Yadav RK, Chaturvedi RK, Dubey SK, Joshi PK, Minhas PS. Potential and hazards associated with sewage irrigation in Haryana. Indian J. Agri. Sci. 2003; 73(5):249-255.
21. Zhao J, Fu G, Lei K. Water Quality Assessment and Apportionment of Pollution Sources of Selected Pollutants in the Min Jiang, a Headwater Tributary of The Yangtze River. Hydrol. Current Res. 2015; 6:211.