e-ISSN No.: 2582-4228

Journal of Indian Association for Environmental Management

Journal homepage: www.http://op.niscair.res.in/index/php/JIAEM/index

Effect of COVID-19 Lockdown on Heavy Metal Contamination in Yamuna River Water of Delhi Region

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Submitted: 03 June 2022 Revised: 22 July 2022 Accepted: 13 August 2022

Abstract: **The present study was conducted to measure the levels of heavy metal pollution in Yamuna River water in the Delhi region during the COVID-19 lockdown period, which provided a unique opportunity to trace the sources of water pollution in the Yamuna segment in the Delhi region. As expected, the concentration of toxic heavy metals (chromium, nickel, copper, zinc, cadmium, and lead) were measured to be below the detection limit (BDL). While iron and manganese were in the ranges of 0.34 - 2.40 mg/l and 0.03 - 2.02 mg/l, respectively. A comparison with the values reported in the literature suggested that the sources of toxic heavy metals in the Yamuna water of Delhi are of primarily anthropogenic origin, whereas iron and manganese can arise from natural as well as anthropogenic sources.**

***Keywords*: COVID-19, Environmental monitoring, Heavy metals, River pollution, Surface water quality, industrial discharge**

I. Introduction

An unprecedented twenty-one-day nationwide lockdown was imposed on March 24, 2020, at midnight by the Government of India as a preventive approach to contain the COVID-19 spread, which was further extended up to May 31, 2020, in three more phases. The total lockdown led to the complete closure of the industries, thus ceasing the economic activities in the nation. This hindered the speed of the flow of resources used in the production process and the goods produced, and the waste discharged into the environment. As a result, industrial effluents were reduced, and measurable data supported clearing pollutants from the atmosphere, soil, and water compartments (Invest India 2020). Amidst the global gloom of COVID-19 causing severe damage to health, the economy, and general societal well-being, the lockdown has provided a unique opportunity to monitor the baseline pollution levels in several environmental matrices, particularly in the cities facing severe anthropogenic pollution issues.

The Yamuna is the longest and the second largest tributary of the Ganga river, originating from the Yamunotri glacier of the Himalayas (38º59'N, 78º2'E), which is situated in the Uttarkashi district of Uttarakhand, India (Sehgal et al. 2012). It covers 396 km distance from its origin Yamunotri to Wazirabad barrage in Delhi (Sharma and Kansal 2011) and flows along the borders of Uttarakhand-Himachal Pradesh-Haryana-Uttar Pradesh States of India. In Delhi, it has only a 22 km long stretch running downstream from Wazirabad to Okhla barrage. However, the catchment of this segment contributes more than 50 percent pollution load in the Yamuna (Sehgal et al., 2012). In this particular segment, Yamuna receives pollutants from several point sources (industrial discharge and municipal sewage) and non-point sources (agricultural runoff). The untreated wastewater from 17 large and small sewer drains, including the largest Najafgarh drain, is discharged into the Yamuna (Said and Hussain 2019). Also, the river stretch before entering Delhi collects discharge from 22 industrial units from Haryana State along with 42 industrial units of Delhi, which release their waste into the Yamuna (Kumar et al. 2019). Hence, the water quality of the Yamuna river degrades radically in its Delhi stretch with the maximum pollution load and remarkably high levels of heavy metals.

Sehgal et al. (2012) investigated the presence of heavy metals in Yamuna river water along its Delhi stretch. The river water samples were collected from 13 locations (~2 km apart from the nearest location) from November to December 2008. Based on the evidence gathered in the study, noticeably elevated concentrations of heavy metals, including chromium (Cr), manganese (Mn), iron (Fe), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As) and lead (Pb) were found in Yamuna's water. Some of the heavy metals, such as Cd, were measured below the detection limit (BDL) in the water samples taken from all thirteen locations (n = 13). The study reported the following ascending order of heavy metal concentrations in water samples (in bracket, average concentration of the respective metal measured above the BDL concentration is presented): Fe (3.63±5.30 mg/l)>Cr (0.98±0.62 mg/l)>Mn (0.28±0.16 mg/l)>Zn (0.19±0.21 mg/l)>Pb (0.20±0.22)>Cu (0.091±0.16)>Ni (0.06±0.03)>Hg (0.20)>As (0.01±0.01)>Cd (BDL). The concentrations of manganese, zinc, and lead were higher than the USEPA water quality standards in most samples. Thus, our previous study reported moderate contamination of heavy metals in Delhi's segment of Yamuna. Industrial discharge was identified as the major contributor to heavy metals in the environment as the geogenic origin of these contaminants is highly unlikely. Other sources of heavy metals may include electronic waste (E-waste) constituents such as nickel batteries, metal coatings, magnetic tapes, and pigments for paints which might have entered the Yamuna water through various drains and non-point sources.

Another study conducted water quality monitoring of the Yamuna at ten sampling sites along the Delhi stretch from July 2012 to August 2013 (Bhattacharya et al., 2015). They reported elevated levels of six heavy metals, namely, Cr (0.05±0.11 mg/l), Ni (0.05±0.03 mg/l), Cu (0.11±0.15 mg/l), Zn (0.69±0.59 mg/l), Cd (0.02±0.02 mg/l) and Pb (0.10±0.07 mg/l). As per their study, rampant discharge of industrial effluent was one of the prime causes of heavy metal pollution in the river water.

Bhardwaj et al. (2017) carried out a heavy metal pollution assessment in the river Yamuna for the same stretch from December 2013 to August 2015. The study also recorded the seasonal variations (pre-monsoon, monsoon, and post-monsoon) in the concentration of seven heavy metals, namely, Cr, Fe, Ni, Cu, Zn, Cd, and Pb. The overall mean concentration (n = 42) of these metals was found in the order as: Fe (10.50±1.64 mg/l) >Cu (2.15±0.52 mg/l) >Zn (1.50 ± 0.68 mg/l) >Ni (0.38±0.10 mg/l) >Cr (0.15±0.06 mg/l) >Pb (0.12±0.03 mg/l) >Cd (0.05±0.05 mg/l). The authors suspected that heavy metal sources could lie in discharge from two major drains (Najafgarh and Shahdara) and/or untreated industrial and domestic effluent from various industrial and residential areas of Delhi and adjoining States.

Yadav and Khandegar (2019) conducted their study in the year 2018 and also reported higher levels of heavy metals concentration such as Cr (0.03 mg/l), Fe (6.2 mg/l), Ni (0.02 mg/l), Cu (0.08 mg/l), Zn (1.36 mg/l), Cd (0.03 mg/l) and Pb (0.02 mg/l).

The studies mentioned above have a non-overlapping water sampling period, but significantly higher concentrations of heavy metals can be noted in all these studies. This reflects a direct correlation between industrial activities and heavy metals in the Yamuna water of Delhi stretch.

The present water pollution monitoring study aimed to investigate the effect of lockdown on the heavy metal concentrations of the Yamuna river flowing in the Delhi region. In this context, the lockdown imposed to contain COVID-19 has provided a unique opportunity for environmental monitoring under an ideal scenario with the complete shutdown of industrial activities. The evidence gathered from this study can help plan necessary steps for the Yamuna pollution abatement and framing the policy decisions for its rejuvenation.

II. MATERIALS & METHODS

Selected sites for surface water sampling

Five sampling spots were selected along the course of the Yamuna river, including S1 -S5 (Geo-tagged), as shown in Fig. 1. The Wazirabad barrage is the entry point of the Yamuna river in Delhi. Therefore, we started sampling (S1) from here and traveled till the Okhla barrage (S5), the exit point of the river. More detailed information about the Yamuna's geography and industries located nearby and connecting drains is given elsewhere (Sehgal et al. 2012).

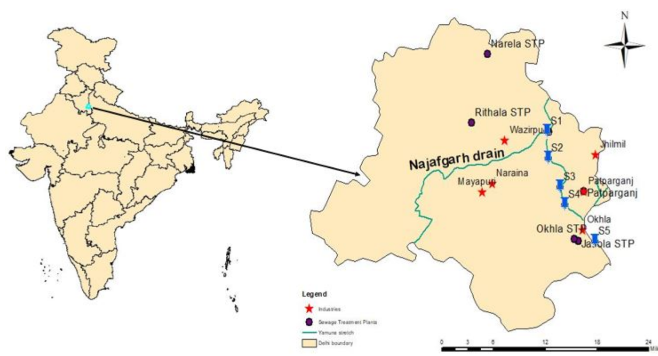

Figure 1: Spatial representation of the Yamuna river water sampling points along its Delhi stretch

(S1-Wazirabad Yamuna bridge, S2-Rajghat old Yamuna bridge, S3-ITO Delhi Sachivalaya bridge, S4-Nizamuddin bridge, S5-Kalindikunj bridge)

TABLE 1
Geographical information of the sampling points and river water pH measured onsite

Sampling points	Sampling site	GPS Coordinates (latitude, longitude)	pH
S1	Wazirabad Yamuna bridge	28° 42' 42.948" N, 77° 13' 52.536" E	7.0
S2	Rajghat old Yamuna bridge	28° 40' 16.176"N, 77° 13' 58.764" E	7.5
S3	ITO Delhi Sachivalaya Bridge	28° 37' 39.216" N, 77° 15' 12.528" E	8.0
S4	Nizamuddin Bridge, Pandar Nagar	28° 36' 3.204" N, 77° 15' 39.456" E	8.0
S5	Kalindi Kunj Bridge	28° 32' 42.036" N, 77° 18' 42.876" E	8.0

Sampling methodology and chemical analysis

The surface water sampling and onsite monitoring were conducted for three consecutive days during the COVID-19 lockdown period (May 13 - 15, 2020). Due to the strict travel restrictions imposed by central and state governments as a precautionary measure, we could collect only limited surface water samples (one from each sampling location for three consecutive days, i.e., three samples from one location, a total of 15 (3*5) samples). A grab water sample from the well-mixed zone of the river was taken in a clean HDPE bottle (capacity = 1 liter), and the pH was measured at the sampling site itself and was found in the range of 7 - 8. To prevent the precipitation of heavy metals, 2 ml nitric acid (trace metal grade, purity = 70%) was added to the sampled water and stored below 4ºC until analysis. Prior to analysis, acid digestion of water samples was performed as per the standard protocol. In short, 2 ml of concentrated HNO_3 was added to 100 ml of water sample in a borosilicate glass beaker (capacity = 250 ml). The sample was covered with a watch glass and heated on a hot plate at 90 - 95ºC until the volume was reduced to ~20 ml. The final volume was adjusted to 100 ml with ultrapure water. These acid digested water samples were then analyzed using ICP-MS (Agilent ICP-MS 7700 series) (APHA, 2012). Instrument blank consisting of ultrapure water and digestion reagent was prepared by the same digestion procedure and analyzed for quality control. All the chemical analysis procedures were completed at AGSS Lab Pvt. Ltd., Delhi.

III. RESULTS AND DISCUSSION

Heavy metals concentration in Yamuna water during lockdown period

In the present study, heavy metals/metalloids such as chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), lead (Pb), and mercury (Hg) were found below the detection concentration as presented in Table 2 (values represented by symbols (<) represent the same). Interestingly, these heavy metals were reported in significantly higher concentrations in our earlier monitoring study (Sehgal et al. 2012) and other studies conducted afterward (Bhattacharya et al. 2015; Bhardwaj et al. 2017; Yadav and Khandegar 2019). The highest concentration of Cr, Ni, Cu, Zn, and Pb in Yamuna water reported in these studies was 1.98, 2.75, 17.64, 28.52, and 1.11 mg/l, respectively. However, non-detectable concentrations of these heavy metals have also been reported at some sampling sites.

Overall, the researchers have measured noticeable concentrations of Cr, Ni, Cu, Zn, and Pb in most of the water samples during the overall ten-year time period (2008 - 2018), as presented in Table 2. Cadmium (Cd) was reported below the detection limit in both our studies. However, several other researchers have reported significantly high concentrations of Cd in Yamuna water. Bhardwaj et al. (2017) found measurable concentrations (0.002 - 0.433 mg/l) of Cd in all 42 samples and reported detectable concentrations of Cr, Ni, Cu, Zn, and Pb in all the water samples collected from different sites. Trace concentration of Pb was reported in all the water samples in the monitoring study conducted by Bhattacharya et al. (2015). However, Arsenic (As) and mercury (Hg) were not analyzed in the other three studies listed in Table 1. The above discussion clearly shows the dilution effect of heavy metals in the Yamuna water. The closure of point sources (industrial activities) and non-point sources (diffuse discharge) of the Yamuna river has most likely prevented the industrial release into the water, thereby reduction in heavy metal pollution. As urban sewage is likely to remain the same even during the COVID-19 lockdown period, industrial wastewater release into the Yamuna is expected to be less or almost nil.. The present study's findings provide indicative evidence of the anthropogenic origin of toxic heavy metals (Cr, Ni, Cu, Zn, Cd, and Pb) in Yamuna water.

Spatial variation in manganese and iron concentration

The manganese (Mn) and iron (Fe) concentrations in the river water get lowered as we moved downstream from the Wazirabad barrage (entry point of Yamuna in Delhi) to Okhla barrage (exit point of Yamuna in Delhi). The spatial variation in the concentrations of these two metals is shown in Fig. 2. At the entry point, both Mn and Fe had the highest concentrations in the river water which were above the permissible limit (0.3 mg/l). However, as we moved downstream, Mn was measured below the permissible limit, while Fe was still found to be above the permissible limit in river water at all five sampling points. These two metals were consistently found in high concentrations at all thirteen sampling points in our earlier monitoring study (Sehgal et al. 2012), with no decreasing trend observed in the concentrations of Mn and Fe. Also, the maximum concentration of Fe in this study was about eight times lesser than our previous study.

High levels of Fe in the Yamuna have also been reported in the literature (Bhardwaj et al., 2017; Yadav and Khandegar, 2019). However, manganese (Mn) concentration was not measured in the studies listed in Table 1. From the above discussion, the source of Fe and Mn in Yamuna river water seems to be geogenic (natural) during the lockdown period, which may arise from the interaction of iron-bearing minerals and groundwater (Sarkar and Shekhar 2018). The most common heavy metals in the industrial effluent are arsenic, cadmium, chromium, copper, lead, nickel, and zinc, all of which cause risks to human health and the environment (Lambert et al. 2000). Arsenic, cadmium, lead, and mercury play no role in human body metabolism and are toxic. Trace concentration of these metals under prolonged exposure through drinking water is often linked with kidney diseases such as chronic kidney disease of uncertain etiology (CKDu) (Lal et al. 2020). The high concentration of toxic heavy metals causes acute toxicity, which is easy to observe and thus regulate. However, exposure to low concentrations of heavy metals in the human body over the years may cause chronic illnesses which are very difficult to monitor and regulate the progression in the population.

TABLE 2

Concentration range of heavy metals in Yamuna water during COVID-19 lockdown and their comparison with literature data

S. No.	Heavy metal	Present study results (mg/l)*	Earlier studies (concentration range, mg/l)				Drinking water permissible limit (BIS:10500)	Inland surface water limit (CPCB)
			Sehgal et al. (2012)	Bhattacharya et al. (2015)	Bhardwaj et al. (2017)*	Yadav and Khandegar (2019)*		
1	Chromium	<0.005	<0.02 - 1.374	0.00 - 0.42	0.003 - 1.983	0.035	0.05	2
2	Manganese	0.027 - 2.017	0.035 - 0.581	ND	ND	ND	0.3	2
3	Iron	0.343 - 2.403	0.471 - 19.76	ND	0.878 - 53.94	6.467	0.3	3
4	Nickel	<0.005	<0.02 - 0.143	0.01 - 0.13	0.001 - 2.748	0.025	0.02	3
5	Copper	<0.005	0.011 - 0.595	0.02 - 0.64	0.018 - 17.64	0.081	1.5	3
6	Zinc	<0.01	<0.005 - 0.754	0.13 - 2.22	0.015 - 28.52	1.365	15	5
7	Arsenic	<0.005	<0.002 - 0.006	ND	ND	ND	0.05	0.2
8	Cadmium	<0.001	<0.002	0.00 - 0.07	0.002 - 0.433	0.037	0.003	2
9	Lead	<0.005	<0.05 - 0.767	0.03 - 0.27	0.007 - 1.112	0.021	0.01	0.1
10	Mercury	<0.0001	<0.004 - 0.201	ND	ND	ND	0.001	0.01

*mean concentration (range - not reported), ND-Not done

From the above discussion, it is pretty clear that the monitored heavy metal level had gone below the detection limit in the surface water samples of the Yamuna in the Delhi region due to the unprecedented COVID-19 lockdown in India. Thus, the addition of industrial wastewater contained with heavy metals during normal days is an unfortunate reality in the Yamuna stretch of the Delhi region.

The industrial waste contaminated Yamuna water is used for irrigation to grow various types of vegetable crops in its floodplains. Also, flood flushes multiple pollutants, including heavy metals, to the agricultural soils of the cultivated area of this region. Subsequently, these heavy metals are transported from soils to vegetable crops and end in the human body. The unsafe concentrations of heavy metals in the edible part of vegetable crops has been reported in our earlier study (Sehgal et al., 2012), and recently a National Environmental Engineering Research Institute (NEERI) study also reported similar results (NEERI 2019). As vegetables are an essential component of the diet, hence long-term dietary exposure to heavy metals could cause life-threatening non-communicable diseases of the liver, kidney, intestines, etc., including cancers (TERI Report, 2019).

Therefore, we recommend necessary policy actions to control the heavy metal-laden industrial discharge into the Yamuna river.

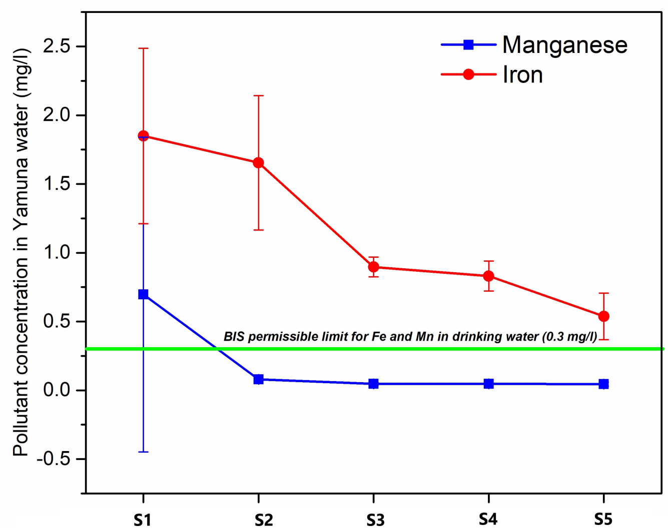

Figure 2: Change in the concentration of manganese and iron in Yamuna water at various locations during the lockdown period (May 13 - 15, 2020). The mean concentration Mn and Fe of three samples are shown with standard deviation as error bars.

IV. CONCLUSION

The COVID-19 pandemic forced the authorities to shut down the industries completely. Thus, a rare opportunity opened to monitor the baseline levels of heavy metal pollution in the Yamuna. This study provides preliminary evidence for the anthropogenic origin of the heavy metals (Cr, Ni, Cu, Zn, Cd, and Pb) causing pollution in the water of Yamuna, Delhi. However, the less toxic metals, iron and manganese are of mostly geogenic origin.

V. References

Bhardwaj, R., Gupta, A., Garg, J.K. (2017). Evaluation of heavy metal contamination using environmetrics and indexing approach for River Yamuna, Delhi stretch, India. Water Sci. 31, 52–66. https://doi.org/10.1016/j.wsj.2017.02.002.

Sehgal, M., Garg, A., Suresh, R., Dagar, P. (2012). Heavy metal contamination in the Delhi segment of Yamuna basin. Environ. Monit. Assess. 184, 1181–1196. https://doi.org/10.1007/s10661-011-2031-9.

Bhattacharya, A., Dey, P., Gola, D., Mishra, A., Malik, A., Patel, N. (2015). Assessment of Yamuna and associated drains used for irrigation in rural and peri-urban settings of Delhi NCR. Environ. Monit. Assess. 187. https://doi.org/10.1007/s10661-014-4146-2.

Yadav, A., Khandegar, V. (2019). Dataset on assessment of River Yamuna, Delhi, India using indexing approach. Data Br. 22, 1–10. https://doi.org/10.1016/j.dib.2018.11.130.

Lal, K., Sehgal, M., Gupta, V., Sharma, A. (2020). Assessment of groundwater quality of CKDu affected Uddanam region in Srikakulam district and across Andhra Pradesh, India. Groundw. Sustain. Dev. 100432. https://doi.org/10.1016/j.gsd.2020.100432.

Sharma, D., Kansal, A. (2011). Water quality analysis of River Yamuna using water quality index in the national capital territory, India (2000–2009). Appl. Water Sci. 1, 147–157. https://doi.org/10.1007/s13201-011-0011-4.

Kumar, M., Sharif, M., Ahmed, S. (2019). Impact of urbanization on the river Yamuna basin. Int. J. River Basin Manag. 0, 1–15. https://doi.org/10.1080/15715124.2019.1613412.

Sarkar, A., Shekhar, S. (2018). Iron contamination in the waters of Upper Yamuna basin. Groundw. Sustain. Dev. 7, 421–429. https://doi.org/10.1016/j.gsd.2017.12.011.

Lambert M, Leven BA, Green RM. New methods of cleaning up heavy metal in soils and water; Environmental science and technology briefs for citizens; Manhattan, KS: Kansas State University; 2000.

Demirezen, D., Aksoy, A. (2004). Accumulation of heavy metals in Typha angustifolia (L.) and Potamogeton pectinatus (L.) living in Sultan Marsh (Kayseri, Turkey). Chemosphere 56, 685–696. https://doi.org/10.1016/j.chemosphere.2004.04.011.

Dawood Muhammad, Fei Chen, Jing Zhao, Guoping Zhang & Feibo Wu (2009) Comparison of EDTA- and Citric Acid-Enhanced Phytoextraction of Heavy Metals in Artificially Metal Contaminated Soil by Typha Angustifolia, International Journal of Phytoremediation, 11:6, 558-574, DOI: 10.1080/15226510902717580.

Bah, A.M., Dai, H., Zhao, J. et al. (2011) Effects of Cadmium, Chromium and Lead on Growth, Metal Uptake and Antioxidative Capacity in Typha angustifolia . Biol Trace Elem Res 142, 77–92. https://doi.org/10.1007/s12011-010-8746-6.

A. T. O'Geen, R. Budd, J. Gan, J. J. Maynard, S. J. Parikh, and R. A. Dahlgren, Mitigating Nonpoint Source Pollution in Agriculture with Constructed and Restored Wetlands. In Donald Sparks, editor: Advances in Agronomy,Vol. 108, Burlington: Academic Press, 2010, pp. 1-76.

Srivastava V., Sarkar A., Singh, S., Singh P., de Araujo Ademir S.F., Singh R.P. (2017). Agroecological Responses of Heavy Metal Pollution with Special Emphasis on Soil Health and Plant Performances. Frontiers in Environmental Science, Vol 5, pp. 64. 10. . https://doi.org/10.3389/fenvs.2017.00064

Invest India (2020). How is COVID-19 impacting the environment around us? https://www.investindia.gov.in/team-india-blogs/how-covid-19-impacting-environment-around-us (accessed June 28, 2020).

NEERI Study (2019). Second Interim Report of the Monitoring Committee. Appointed by the Hon'ble National Green Tribunal Vide order Dated July 26 2019. https://yamuna-revival.nic.in/wp-content/uploads/2019/07/Second-Interim-Report-of-Yamuna-Monitoring-Committee-27.05.2019.pdf (accessed July 22, 2022).

TERI Policy Brief (2019). Contamination of Heavy Metals in India: Health Effects and Remediation Measures. https://www.teriin.org/policy-brief/contamination-heavy-metals-india (accessed July 22, 2022).