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Impact of Hindon River Water on Selected Riparian Flora (*Azadirachta Indica* and *Acacia Nilotica*) with special Reference to Heavy Metals

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ABSTRACT: The present study aims to identify the impact of polluted aquatic body i.e. River Hindon on two selected riparian flora i.e. *Azadirachta indica and Acacia nilotica*. During the course of study the average concentration of different metals in river water was found as Iron (Fe) 11.27ppm±3.50, Manganese (Mn) 4.00ppm±1.26, Cadmium (Cd) 0.08ppm±0.07, Nickel (Ni) 0.63ppm±0.17 and Zinc (Zn) 1.46ppm±0.38 respectively. The average concentration of heavy metals in *A. indica* of sampling site was found as Iron (Fe) 24.76ppm±6.25, Manganese (Mn) 5.04ppm±1.38, Cadmium (Cd) 0.05ppm±0.05, Nickel (Ni) 0.34ppm±0.20 and Zinc (Zn) 53.92ppm±19.29 respectively while in control site plant average concentration was found as Iron (Fe) 17.18ppm±3.96, Manganese (Mn) 3.63ppm±1.63, Cadmium (Cd) 0.02ppm±0.03, Nickel (Ni) 0.16ppm±0.06 and Zinc (Zn) 31.26ppm±12.11 respectively and average concentration in *A. nilotica* of sampling sites was found as Iron (Fe) 45.78ppm±10.67, Manganese (Mn) 42.08ppm±11.98, Cadmium (Cd) 0.59ppm±0.51, Nickel (Ni) 40.83ppm±12.16 and Zinc (Zn) 144.10ppm±49.94 respectively while average concentration in control site plant was found as Iron (Fe) 27.76ppm±9.49, Manganese (Mn) 22.75ppm±7.09, Cadmium (Cd) 0.42ppm±0.27, Nickel (Ni) 23.53ppm±8.02 and Zinc (Zn) 96.61ppm±24.78 respectively. One way ANOVA shows statistically significant difference between sampling site plant and control site plant for all the studied metals except Cr in *A. nilotica* $F(3, 42) = 0.589$, $P= 0.626$. A big difference was found in the concentration of metals between sampling site plants and control site plant. In case of metal uptake *A. nilotica* was found more efficient as comparison to *A. indica.*

Keywords: Riparian vegetation, terrestrial ecosystems, sluggish flow, *A.nilotica, A. indica*.

INTRODUCTION

The metals which have the density higher than 5gm/cm^3 (Lide, 1993) and they exist in the environment naturally are defined as heavy metals. River bank vegetation is ecologically termed as riparian flora and is highly dynamic. It links terrestrial and aquatic habitat, under the influence of waterways such as rivulet banks or Riverbanks, is represented by a particular type of vegetation that grows along the sides of Rivers, which are called the

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River's riparian zone (Dutta et al., 2011). The function of a riparian zone of any aquatic body and plants on the bank is to absorb and filter out sediment and debris and thus helps in providing unique habitats for some organisms. Riparian areas support some of the most diverse and productive of all plant communities. Easy availability of water and fertile soil support a greater plant biomass than is usually found in upland areas, resulting in forests with the different type of species and complex vertical structures (Ilhardt et al., 2000). If we do not protect the riparian community from degradation, the quality of water and plants and other biological species will drop down different types of pollution causing threats to Riparian flora which may affect the quality of the ecosystem. In the areas which are dominated by rivers, lakes and streams, forests along the bank of these water bodies provide many important ecological services which are critical in maintaining watershed productivity and sustainability (Gregory 1999; Naiman et al., 2005). These forests (riparian flora) regulate the flux of energy, nutrients and biotic interchanges between aquatic and terrestrial ecosystems (Ilhardt et al., 2000; Naiman et al., 2000) and consequently have been described as functional ecotones. Some previous studies on River Hindon (Bhutiani et al., 2017; Jain & Sharma, 2006; Mishra et al., 2015; Ruhela et al., 2017; Suther et al., 2010; Rizvi et al., 2015 and Rizvi et al., 2016) revealed that industrial and municipal effluents pose great stress on the health of River. The objective of the present study was to assess the Hindon river in terms of heavy metals and to conclude the effect of these heavy metals of the selected riparian flora i.e. *Azadirachta indica* and *Acacia nilotica*.

MATERIAL AND METHODS

Hindon River, a tributary of Yamuna River is a River in India that originates in the Saharanpur District, Uttar Pradesh. The River is entirely rain fed and its catchment area (7,083km^2) is a part of the Indo Gangetic Plain, composed of Pleistocene and sub recent alluvium and lies between the latitude 28^{o}30’ to 30^{o}15’N and longitude 77^{o}20’ to 77^{o}50’E and flows 400 km through six districts, including Muzaffarnagar, Meerut, Baghpat, Ghaziabad and Gautambudh Nagar until its confluence with the Yamuna. The River is characterized by sluggish flow throughout the year, except during monsoon when rainfall causes a manifold increase in the runoff (Suthar et al., 2010). The study area of the River under present study ranged from its entrance in Ghaziabad to its confluence with the Yamuna River in Tilwada village, Noida. Total 4 sites were identified and selected for the collection of samples (Fig 1).

For the sampling of selected riparian flora, the selected plants were identified at each of the four sampling site and a site approximately 10km from the river was also selected as control site. For the present study of River Hindon, the water samples were collected on monthly basis from different sampling sites viz. Hindon Barrage, Ghaziabad (1), Indrapuram, Ghaziabad (2), Near Vishnu Nagar, Noida (3) and Dadri Road, Noida (4) during January 2013 to December 2014 in morning hours. Selected heavy metals were analyzed following the standard methods of A.P.H.A (2012); Trivedi & Goel (1986); Khanna & Bhutiani (2008) using the Atomic Absorption Spectroscopy (AAS). The riparian flora was collected from the bank of Hindon River from all the sampling sites and from control site which was an unproductive land and about 10 Km away from Hindon River. Fresh leaves of two riparian flora i.e. *A. indica* (Fig.2) *and A. nilotica* (Fig. 3) were selected for the experimental analysis of heavy metals to conclude the effect of Hindon River water on the riparian flora.

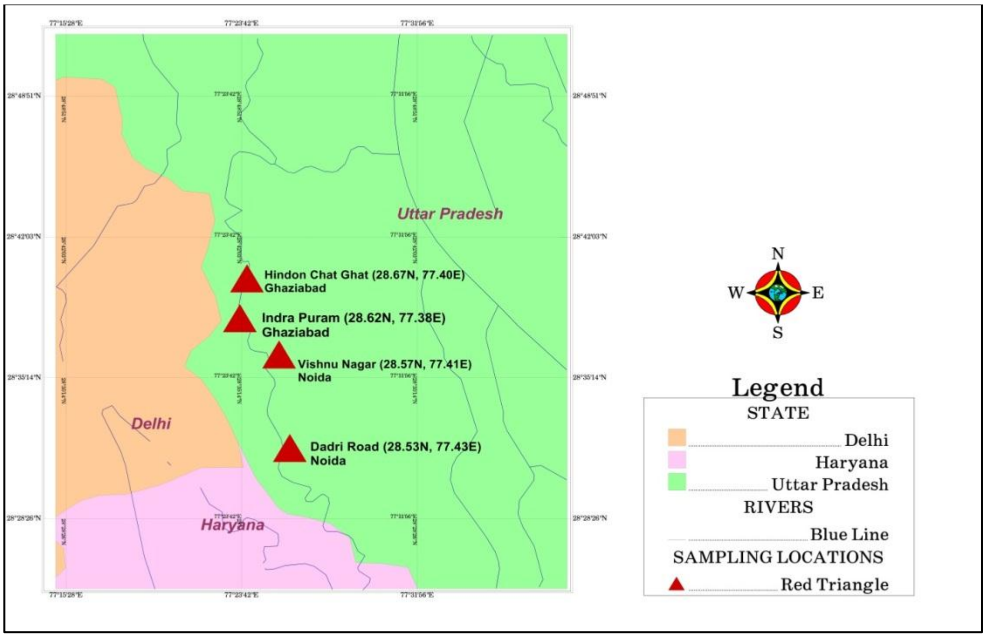

Fig. 1. Showing all the study sites of Hindon River in the Google map

Fig. 2. Showing leaves of Riparian Flora found at study sites (*Acacia nilotica*)

Fig. 3. Showing leaves of Riparian Flora found at study sites *(Azadirachta indica)*

RESULTS AND DISCUSSION

Monthly average values of heavy metals of Hindon River during the study period (2013-2014) including all the sites are tabulated in the Table 1. Average values of heavy metals in Riparian flora during the study period are tabulated in the Table 2 and 3. Results of one way ANOVA of Hindon River metal concentration and riparian plants are given in table no 4, 5 and 6 respectively.

During the study period maximum average concentration (20.38ppm±1.66) of iron was found in summer season (May) this may be due to less water in river, high solar radiation and high evaporation rates of water resulting in accumulation of metal concentration and the minimum concentration of iron was found (8.42ppm±1.53) in monsoon season (August) may be due to high flow and high water level and dilution effect (Asa et al., 2015; Cheng, 2003) while the average concentration was found as 11.27ppm±3.50. A more or less same trend of iron concentration was observed by Mishra et al., 2015 and Prabu et al., 2011. One way ANOVA shows statistically significant differences in iron levels between different sites $F(3, 92) = 3.60$, $P = 0.016$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in iron levels between Hindon barrage, Indrapuram, Vishnu Nagar, and Dadri Road.

Table 1. Showing average variation in values of Metal Concentration during the study period (2013-2014)

Month/ Parameters	Fe (ppm)	Mn (ppm)	Cu (ppm)	Cd (ppm)	Ni (ppm)	Cr (ppm)	(Zn ppm)
January	8.66 ±1.97	2.86 ±0.81	0.12 ±0.02	0.01 ±0.02	0.58 ±0.08	0.12 ±0.12	0.96 ±0.41
February	8.73 ±0.10	3.45 ±0.26	0.10 ±0.00	0.08 ±0.03	0.41 ±0.17	0.18 ±0.02	1.26 ±0.08
March	11.05 ±3.22	3.51 ±0.37	0.15 ±0.05	0.18 ±0.09	0.64 ±0.00	0.22 ±0.08	1.55 ±0.28
April	11.77 ±1.73	3.76 ±0.18	0.13 ±0.05	0.05 ±0.03	0.62 ±0.02	0.19 ±0.09	1.39 ±0.31
May	20.38 ±1.66	7.11 ±0.56	0.34 ±0.06	0.19 ±0.09	1.00 ±0.17	0.27 ±0.01	1.76 ±0.09
June	15.79 ±6.02	6.02 ±1.73	0.21 ±0.27	0.22 ±0.01	0.91 ±0.27	0.17 ±0.16	2.25 ±0.60
July	9.52 ±1.05	3.57 ±0.46	0.10 ±0.12	0.08 ±0.05	0.61 ±0.11	0.07 ±0.01	1.88 ±0.87
August	8.42 ±1.53	2.95 ±0.77	0.13 ±0.02	0.03 ±0.04	0.66 ±0.14	0.04 ±0.06	1.48 ±0.76
September	9.77 ±2.74	3.49 ±0.17	0.11 ±0.04	0.03 ±0.04	0.61 ±0.33	0.07 ±0.10	1.31 ±0.23
October	10.73 ±3.68	3.47 ±0.42	0.12 ±0.05	0.03 ±0.04	0.45 ±0.26	0.17 ±0.13	1.30 ±0.27
November	11.00 ±2.83	4.09 ±0.28	0.15 ±0.05	0.05 ±0.00	0.53 ±0.11	0.24 ±0.24	1.47 ±0.55
December	9.37 ±0.43	3.72 ±0.27	0.14 ±0.01	0.07 ±0.07	0.55 ±0.14	0.11 ±0.08	0.90 ±0.14
Average ±SD	11.27 ±3.50	4.00 ±1.26	0.15 ±0.07	0.08 ±0.07	0.63 ±0.17	0.16 ±0.07	1.46 ±0.38

The availability of micronutrients to plant roots depends on the pH level of the soil with iron more readily available in soil with a low pH (Wintz et al., 2002). During the study period minimum average concentration of iron in *A. indica* of sampling site plant (SSP) and control site plant (CSP) was found 24.16ppm±4.26 and 11.85ppm±0.44 and maximum average concentration was found 89.86ppm±25.09 and 48.66ppm±9.21 while the average concentration was found 53.92ppm±19.29 and 31.26ppm±12.11 respectively. One way ANOVA shows statistically significant differences in Fe levels between SSP and CSP, F (3, 44) =6.459, P =0.001, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Fe levels between SSP and CSP. During the study period minimum average concentration of iron in *A. nilotica* of SSP and CSP was found 68.94ppm±3.76 and 51.92ppm±21.51 and maximum average concentration was found 240.63ppm±59.30 and 127.63ppm±23.48 while the average concentration was found 144.10 ppm±49.94 and 96.61ppm±24.78 respectively. One way ANOVA shows statistically significant differences in Fe levels between SSP and CSP, F (3, 44) =4.239, P =0.010, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Fe levels between SSP and CSP. A large variation in iron concentration in both the plant (*A. indica* and *A. nilotica*) was found (approximately 1.5 times) between SSP and CSP, this may be due to high concentration of iron in river water and sediments. Air pollution may be responsible for some amount of heavy metals in plants. The concentration of iron was found higher in both CSP and SSP when compared with other metal indicates that the source of iron in plants could be geogenic as well as anthropogenic activities.

During the study period maximum average concentration (7.11ppm±0.56) of manganese was found in summer season (May) may be due to high evaporation in summer season because industrial activities were same throughout the year and minimum average concentration (2.86ppm±0.81) was found in winter season (January) while the average concentration was found as 4.00ppm±1.26. A more or less same trend of manganese concentration was observed by Ruhela et al., 2017; Khanna et al., 2014 and Prabu et al., 2011. One way ANOVA shows statistically significant differences in manganese level between different sites F (3, 92) = 9.75, P = 0.000, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in manganese levels between Hindon barrage, Indrapuram, Vishnu Nagar, and Dadri Road.

During the study period minimum average concentration of manganese in *A. indica* of SSP and CSP was found 17.22ppm±6.48 and 11.97ppm±6.80 and maximum average concentration was found 35.09ppm±1.33 and 24.31ppm±6.83 while the average concentration was found 24.76ppm±6.25 and 17.18ppm±3.96 respectively. One way ANOVA shows statistically significant differences in Mn levels between SSP and CSP, F(3, 44) = 5.381, P =0.003, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Mn levels between SSP and CSP. During the study period minimum average concentration of manganese in *A. nilotica* of SSP and CSP was found 29.30ppm±4.02 and 15.26ppm±1.41 and maximum average concentration was found 60.63ppm±7.74 and 49.21ppm±25.38 while the average concentration was found 45.78ppm±10.67 and 27.76ppm±9.49 respectively. One way ANOVA shows statistically significant differences in Mn levels between SSP and CSP, F (3, 44) = 6.832, P =0.001, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Mn levels between SSP and CSP. More or less same trend of manganese in plant leaf was found by Anicic et al., 2007.

During the study period maximum

average concentration (0.34ppm±0.06) of copper was found in summer season (May) and minimum average concentration (0.10ppm±0.00) was found in winter season (February) while the average concentration was found as 0.15ppm±0.07. Similar results were obtained by Karikari & Ansa-Asare, 2006; Asa et al., 2015; Mishra et al., 2015; Bhutiani et al., 2017. One way ANOVA shows statistically significant differences in copper levels between different sites $F(3, 92) = 6.29$, $P = 0.001$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in copper levels between Hindon barrage, Indrapuram, Vishnu Nagar, and Dadri Road.

Copper (Cu) is an essential micronutrient for plant growth and development, it having also toxic property (Kabir et al., 2009). It plays important role in assimilation of CO_2 and synthesis ATP (Mohnish & Kumar, 2015). More concentration of Cu in soil causes injury to plants. This leads to retardation in plant growth and chlorosis. During the study period minimum average concentration of copper in *A. indica* of SSP and CSP was found 0.57ppm±0.22 and 0.21ppm±0.10 and maximum average concentration was found 1.86ppm±0.37 and 12.30ppm±15.13 while the average concentration was found 1.29ppm±0.40 and 1.73ppm±3.37 respectively. One way ANOVA shows statistically significant differences in Cu levels between SSP and CSP, $F(3, 44) = 4.167$, $P = 0.011$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Cu levels between SSP and CSP. During the study period minimum average concentration of copper in *A. nilotica* of SSP and CSP was found 27.99ppm±2.66 and 14.69ppm±10.20 and maximum average concentration was found 81.61ppm±13.65 and 35.04 ppm±44.43 while the average concentration was found 52.33ppm±16.22 and 24.34 ppm±6.98 respectively. One way ANOVA shows statistically significant differences in Cu levels between SSP and CSP, $F(3, 44) = 23.944$, $P = 0.000$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Cu levels between SSP and CSP.

During the study period maximum average concentration (0.22ppm±0.01) of cadmium was found in summer season (June) and minimum average concentration (0.01ppm±0.02) of cadmium was found in winter season (January) while the average concentration was found as 0.08ppm±0.07.A more or less same trend of cadmium concentration was observed by Taghinia et al., 2010; Bhutiani et al., 2016; Suthar et al., 2009. One way ANOVA shows statistically significant differences in cadmium levels between different sites $F(3, 92) = 5.48$, $P = 0.002$. Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in cadmium levels between Hindon barrage, Indrapuram, Vishnu Nagar, and Dadri Road. The higher concentration of Cd shows visible symptoms of chlorosis, inhibition of plant growth, browning of root tips and lastly death of plant (Mohanpuria & Yadav, 2007; Guo et al., 2008).

During the study period minimum average concentration of cadmium in *A. indica* was found BDL both in sampling site and CSP and maximum average concentration was found 0.14ppm±0.20 and 0.10ppm±0.14 while the average concentration was found 0.05ppm±0.05 and 0.02ppm±0.03respectively. One way ANOVA shows statistically significant differences in Cd levels between SSP and CSP, $F(3, 44) = 6.594$, $P = 0.001$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Cd levels between SSP and CSP. During the study period minimum average concentration of cadmium in *A. nilotica* of SSP and CSP was found respectively 0.03ppm ±0.01 and 0.02ppm±0.03 and maximum average concentration was found 1.69ppm±2.34 and 0.88ppm±0.91 while the average concentration was found 0.59ppm±0.51 and 0.42ppm±0.27

Table 2. Showing average variation in different metal concentration in *Azadiracta indica* during the study period (2013-2014)

Parameters /Month	Manganese (Mn) in ppm		Zinc (Zn) in ppm		Copper (Cu) in ppm		Cadmium (Cd) in ppm		Nickel (Ni) in ppm		Chromium (Cr) in ppm		Iron (Fe) in ppm	
	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site
January	35.09± 1.33	15.63 ±9.15	3.64 ±0.00	1.79 ±0.80	0.98 ±0.00	0.71 ±0.72	0.03 ±0.05	0.01 ±0.01	0.20 ±0.11	0.07 ±0.09	0.32 ±0.00	0.00 ±0.00	33.62 ±4.95	16.23 ±4.11
February	23.26 ±1.22	17.19 ±1.34	4.59 ±0.00	2.68 ±2.11	1.08 ±0.07	0.36 ±0.28	0.00 ±0.00	0.00 ±0.00	0.23 ±0.03	0.11 ±0.15	0.20 ±0.01	0.00 ±0.00	25.38 ±7.39	21.08 ±11.43
March	32.40 ±1.07	17.75 ±12.01	6.83 ±1.61	4.90 ±4.58	1.27 ±0.57	0.21 ±0.10	0.01 ±0.01	0.01 ±0.01	0.19 ±0.12	0.18 ±0.02	0.26 ±0.13	0.00 ±0.00	24.16 ±4.26	18.44 ±4.41
April	25.73 ±1.07	12.84 ±5.21	3.81 ±2.06	5.23 ±3.88	1.36 ±1.08	0.41 ±0.22	0.04 ±0.05	0.04 ±0.03	0.10 ±0.08	0.15 ±0.16	0.19 ±0.04	0.14 ±0.04	44.66 ±0.00	11.85 ±0.44
May	30.45 ±5.17	12.02 ±8.30	5.68 ±2.14	3.52 ±0.35	1.53 ±0.69	12.30 ±15.13	0.10 ±0.14	0.04 ±0.06	0.15 ±0.11	0.26 ±0.33	0.20 ±0.13	0.03 ±0.04	60.75 ±30.05	36.17 ±12.66
June	20.59 ±3.43	18.38 ±10.03	8.14 ±0.00	4.95 ±1.11	1.67 ±0.45	1.15 ±0.94	0.09 ±0.12	0.10 ±0.14	0.65 ±0.65	0.17 ±0.24	0.29 ±0.06	0.01 ±0.01	60.15 ±1.20	34.82 ±1.91
July	18.32 ±4.47	17.71 ±4.74	5.29 ±3.79	2.74 ±1.02	1.27 ±0.57	1.91 ±1.08	0.13 ±0.18	0.01 ±0.01	0.49 ±0.33	0.26 ±0.36	0.28 ±0.10	0.11 ±0.16	67.35 ±7.42	47.33 ±29.11
August	31.52 ±0.50	23.82 ±8.01	5.20 ±0.11	7.07 ±0.12	1.86 ±0.37	1.43 ±1.51	0.14 ±0.20	0.01 ±0.01	0.59 ±0.14	0.22 ±0.08	0.23 ±0.09	0.14 ±0.20	68.09 ±18.50	48.66 ±9.21
September	17.22 ±6.48	17.68 ±2.98	4.16 ±0.00	1.90 ±0.33	1.53 ±0.69	0.55 ±0.02	0.04 ±0.01	0.02 ±0.02	0.45 ±0.16	0.12 ±0.16	0.29 ±0.02	0.00 ±0.00	57.95 ±4.74	41.16 ±26.91
October	24.59 ±6.87	24.31 ±6.83	5.08 ±4.33	3.95 ±2.58	1.67 ±0.45	0.27 ±0.15	0.03 ±0.05	0.00 ±0.00	0.53 ±0.44	0.08 ±0.11	0.11 ±0.00	0.00 ±0.00	89.86 ±25.09	32.18 ±22.73
November	18.12 ±2.70	16.85 ±7.81	3.29 ±0.00	1.90 ±1.22	0.70 ±0.07	0.36 ±0.19	0.00 ±0.00	0.00 ±0.00	0.42 ±0.37	0.13 ±.05	0.08 ±0.00	0.06 ±0.08	64.36 ±6.57	37.75 ±19.11
December	19.91 ±1.85	11.97 ±6.80	4.76 ±0.86	2.97 ±1.16	0.57 ±0.22	1.09 ±0.51	0.00 ±0.00	0.00 ±0.00	0.11 ±0.02	0.17 ±0.08	0.23 ±0.00	0.00 ±0.00	50.69 ±6.63	29.42 ±2.95
Average ±SD	24.76 ±6.25	17.18 ±3.96	5.04 ±1.38	3.63 ±1.63	1.29 ±0.40	1.73 ±3.37	0.05 ±0.05	0.02 ±0.03	0.34 ±0.20	0.16 ±0.06	0.22 ±0.07	0.04 ±0.06	53.92 ±19.29	31.26 ±12.11

Table 3. Showing average variation in different metal concentration in *Acacia nilotica* during the study period (2013-2014)

Parameters /Month	Manganese (Mn) in ppm		Zinc (Zn) in ppm		Copper (Cu) in ppm		Cadmium (Cd) in ppm		Nickel (Ni) in ppm		Chromium (Cr) in ppm		Iron (Fe) in ppm	
	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site	Plant on site	Plant on control site
January	48.51 ±30.69	31.98 ±18.79	29.80 ±2.21	13.90 ±6.56	41.06 ±6.81	19.39 ±9.56	0.06 ±0.00	0.49 ±0.69	38.12 ±9.90	29.69 ±5.05	0.05 ±0.02	0.02 ±0.02	177.28 ±13.92	88.39 ±23.66
February	59.81 ±16.53	25.24 ±1.29	39.72 ±2.02	11.76 ±10.61	66.27 ±5.49	20.68 ±20.59	0.04 ±0.01	0.02 ±0.03	34.19 ±15.61	18.15 ±15.56	0.05 ±0.02	0.01 ±0.02	102.70 ±0.57	90.66 ±7.72
March	48.86 ±8.85	39.19 ±4.34	50.05 ±11.41	19.89 ±6.54	54.74 ±9.18	21.70 ±24.85	0.59 ±0.48	0.05 ±0.06	21.54 ±14.09	25.74 ±33.62	0.04 ±0.01	0.03 ±0.04	94.92 ±22.32	62.72 ±12.01
April	47.56 ±5.19	22.42 ±9.64	33.66 ±2.84	23.07 ±4.53	50.32 ±15.83	33.87 ±15.16	1.16 ±1.49	0.81 ±1.14	55.77 ±0.86	31.46 ±4.66	0.09 ±0.09	0.13 ±0.18	68.94 ±3.76	74.80 ±10.68
May	60.63 ±7.74	26.96 ±20.80	46.11 ±7.00	29.31 ±31.14	81.61 ±13.65	35.12 ±36.76	0.32 ±0.38	0.88 ±0.91	54.47 ±18.09	13.85 ±3.24	0.03 ±0.00	0.02 ±0.03	188.14 ±29.70	105.23 ±4.24
June	50.30 ±12.76	49.21 ±25.38	58.64 ±3.49	15.94 ±0.46	66.26 ±8.89	35.04 ±44.43	1.69 ±2.34	0.26 ±0.37	57.76 ±3.43	21.61 ±3.70	0.07 ±0.06	0.00 ±0.00	152.09 ±41.41	114.96 ±15.93
July	53.16 ±19.21	24.42 ±2.57	55.94 ±14.40	25.66 ±23.65	47.03 ±12.99	17.32 ±11.40	0.59 ±0.83	0.37 ±0.52	40.55 ±10.89	31.67 ±36.13	0.09 ±0.09	0.08 ±0.11	183.44 ±19.94	118.66 ±89.80
August	48.39 ±9.57	32.50 ±6.58	37.76 ±4.95	19.08 ±3.23	71.71 ±7.40	25.05 ±19.19	0.42 ±0.42	0.30 ±0.37	50.41 ±1.20	35.56 ±1.73	0.05 ±0.01	0.00 ±0.00	138.34 ±15.88	127.21 ±67.96
September	33.00 ±4.42	26.38 ±10.94	24.12 ±6.43	25.03 ±8.34	38.74 ±3.51	26.87 ±30.17	0.44 ±0.57	0.55 ±0.77	34.76 ±17.59	27.14 ±26.85	0.05 ±0.03	0.24 ±0.16	170.86 ±16.07	87.92 ±2.45
October	40.56 ±12.25	15.26 ±1.41	57.19 ±20.92	35.48 ±12.94	47.33 ±10.96	14.69 ±10.20	1.17 ±1.65	0.50 ±0.41	43.29 ±10.10	19.55 ±5.20	0.03 ±0.01	0.08 ±0.11	240.63 ±59.30	109.23 ±62.27
November	29.30 ±4.02	23.49 ±3.74	44.93 ±9.96	30.88 ±4.66	34.88 ±6.83	20.98 ±22.37	0.55 ±0.75	0.60 ±0.80	21.85 ±0.71	8.83 ±5.45	0.04 ±0.02	0.03 ±0.04	108.92 ±11.53	51.92 ±21.51
December	29.34 ±11.05	16.06 ±0.11	27.00 ±6.48	23.01 ±9.66	27.99 ±2.66	21.43 ±14.17	0.03 ±0.01	0.26 ±0.36	37.26 ±5.81	19.20 ±13.63	0.04 ±0.00	0.03 ±0.04	102.93 ±9.62	127.63 ±23.48
Average ±SD	45.78 ±10.67	27.76 ±9.49	42.08 ±11.98	22.75 ±7.09	52.33 ±16.22	24.34 ±6.98	0.59 ±0.51	0.42 ±0.27	40.83 ±12.16	23.53 ±8.02	0.05 ±0.02	0.06 ±0.07	144.10 ±49.94	96.61 ±24.78

respectively. One way ANOVA shows statistically significant differences in Cd levels between SSP and CSP, $F (3, 44) = 10.476$, $P = 0.000$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Cd levels between SSP and CSP. Similar Pattern of cadmium concentration in the leaves of plants was found by Eghbal et al., 2019. Increasing concentration of these metals may cause health risk to human beings in the study area through direct and indirect consumption (Nasrabadi & Bidabadi, 2013; Nasrabadi et al., 2015).

During the study period maximum average concentration (1.00 ppm ±0.17) of nickel was found in summer season (May) and minimum average concentration (0.41ppm±0.17) was found in winter season (February) while the average concentration was found as 0.63ppm±0.17. A more or less same trend of nickel concentration was observed by Asa et al., 2015. One way ANOVA shows statistically significant differences in nickel levels between different sites $F (3, 92) = 31.71$, $P = 0.000$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in nickel levels between Hindon barrage, Indrapuram, Vishnu Nagar, and Dadri Road.

Nickel reduces photosynthetic activity of plants (Krupa et al., 1993). During the study period minimum average concentration of nickel in *A. indica* of SSP and CSP was found 0.10ppm±0.08 and 0.07ppm±0.09 and maximum average concentration was found 0.65ppm ±0.65 and 0.26ppm ±0.33 while the average concentration was found 0.34ppm±0.20 and 0.16ppm±0.06 respectively. One way ANOVA shows statistically significant differences in Ni levels between SSP and CSP, $F (3, 44) = 8.161$, $P = 0.000$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Ni levels between SSP and CSP. During the study period minimum average concentration of nickel in *A. nilotica* of SSP and CSP was found 21.54ppm±14.09 and 8.83 ppm±5.45 and maximum average concentration was found 57.76ppm ±3.43 and 35.56 ppm ±1.73 while the average concentration was found 40.83ppm±12.16 and 23.5 ppm±8.02 respectively. One way ANOVA shows statistically significant differences in Ni levels between SSP and CSP, $F (3, 44) = 8.452$, $P = 0.00$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Ni levels between SSP and CSP.

During the study period maximum average concentration (0.27ppm±0.01) of chromium was found in summer season (May) and the minimum average concentration (0.04ppm±0.06) was found in rainy season (August) while the average concentration was found as 0.16ppm±0.07. A more or less same trend of chromium concentration was observed by Lohani et al., 2008; Mishra et al., 2015. One way ANOVA shows statistically significant differences in chromium levels between different sites $F (3, 92) = 8.27$, $P = 0.000$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in chromium levels between Hindon barrage, Indrapuram, Vishnu Nagar, and Dadri Road.

High chromium concentration can disturb the chloroplast structure there by damaging the photosynthetic process. Chromium is one of the important metal that affect photosynthesis in terms of CO_2 fixation, electron transport and enzyme activities. During the study period minimum average concentration of chromium in *A. indica* of SSP and CSP was found 0.08ppm±0.00 and BDL and maximum average concentration was found 0.32ppm±0.00 and 0.14ppm±0.20 while the average concentration was found 0.22ppm±0.07 and 0.04ppm±0.06 respectively. One way ANOVA shows statistically significant differences in Cr levels between SSP and CSP, $F (3, 44) = 18.270$, $P = 0.000$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Cr levels between SSP and CSP. During the study period minimum average concentration of chromium in *A. nilotica* of SSP and CSP was found 0.03ppm±0.00 and BDL and maximum average concentration was found 0.09ppm±0.09 and 0.24ppm±0.16 while the average concentration was found 0.05ppm±0.02 and 0.06ppm±0.07 respectively. One way ANOVA shows statistically insignificant differences in Cr levels between SSP and CSP, $F(3, 44) = 0.589$, $P = 0.626$, Games Howell post hoc test shows that there are statistically no significant differences ($p>0.05$) in Cr levels between SSP and CSP.

During the study period maximum average concentration (2.25ppm±0.60) of zinc was found in summer season (June) and minimum average concentration (0.90ppm±0.14) of zinc was found in winter season (December) while the average concentration was found as 1.46ppm±0.38. A more or less same trend of zinc concentration was observed by Mishra et al., 2015. One way ANOVA shows statistically significant differences in zinc levels between different sites $F(3, 92) = 8.85$, $P = 0.000$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in zinc levels between Hindon barrage, Indrapuram, Vishnu Nagar, and Dadri Road.

During the study period minimum average concentration of zinc in *A. indica* of SSP and CSP was found 3.29ppm±0.00 and 1.79ppm±0.80 and maximum average concentration was found 8.14ppm±0.00 and 7.07ppm±0.12 while the average concentration was found 5.04ppm±1.38 and 3.63ppm±1.63 respectively. One way ANOVA shows statistically insignificant differences in Zn levels between SSP and CSP, $F(3, 44) = 2.155$, $P = 0.107$, Games Howell post hoc test shows that there are statistically no significant differences ($p>0.05$) in Zn levels between SSP and CSP. During the study period minimum average concentration of zinc in *A. nilotica* of SSP and CSP was found 24.12ppm±6.43 and 11.76ppm±10.61 and maximum average concentration was found 58.64ppm±3.49 and35.48ppm±12.94 while the average concentration was found 42.08ppm±11.98 and22.75ppm±7.09 respectively. One way ANOVA shows statistically significant differences in Zn levels between SSP and CSP, $F(3, 44) = 9.952$, $P = 0.000$, Games Howell post hoc test shows that there are statistically significant differences ($p<0.05$) in Zn levels between SSPand control site.

Table 4. Result of One way ANOVA to assess site wise variation in Hindon River

S.No	Site wise Variation						
	Parameter	**Sum of Squares**	**Df**	**Within Group**	**Mean Square**	**F**	**Significance**
1	Fe	180.765	3	92	60.255	3.604	0.016
2	Zn	64.492	3	92	21.490	9.759	0.000
3	Cu	0.241	3	92	0.080	6.290	0.001
4	Cd	0.113	3	92	0.038	5.481	0.002
5	Ni	6.951	3	92	2.317	31.714	0.000
6	Cr	0.289	3	92	0.096	8.274	0.000
7	Mn	32.192	3	92	10.731	8.852	0.000

Table 5. Result of One way ANOVA to assess the impact of Hindon River on *Azadiracta indica*

S.No	Site wise Variation						
	Parameter	**Sum of Squares**	**Df**	**Within Group**	**Mean Square**	**F**	**Significance**
1	Mn	733.910	3	44	244.637	5.381	0.003
2	Zn	28.527	3	44	9.509	2.155	0.107
3	Cu	4.950	3	44	1.650	4.167	0.011
4	Cd	0.068	3	44	0.023	6.594	0.001
5	Ni	0.979	3	44	0.326	8.161	0.000
6	Cr	0.393	3	44	0.131	18.270	0.000
7	Fe	6906.051	3	44	2302.017	6.459	0.001

Table 6. Result of One way ANOVA to assess the impact of Hindon River on *Acacia nilotica*

S.No	Site wise Variation						
	Parameter	**Sum of Squares**	**Df**	**Within Group**	**Mean Square**	**F**	**Significance**
1	Mn	3948.841	3	44	1316.280	6.832	0.001
2	Zn	4816.241	3	44	1605.414	9.952	0.000
3	Cu	15031.952	3	44	5010.651	23.944	0.000
4	Cd	10.372	3	44	3.457	10.476	0.000
5	Ni	4905.469	3	44	1635.156	8.452	0.000
6	Cr	0.009	3	44	0.003	0.589	0.626
7	Fe	27382.194	3	44	9127.398	4.239	0.010

CONCLUSION

Although heavy metals are beneficial for the plants when they are present in required amount but when they present in excess, they become harmful to plants. Therefore ,it is essential to study the impact of polluted water on plants for better understanding of heavy metal toxicity on plants and allied areas to maintain the ecological harmony of our planet. From the above study it may be concluded that plants with excess of heavy metals showed increased stomatal resistance, decreased transpiration rate and alteration in water relation. There are two aspects of the study of interaction of plants and heavy metals, first the heavy metals works negatively on the plants and on other hand, plants have their own resistance mechanisms to detoxify the toxic effects of heavy metal pollution. Heavy metal enters in the plant by two pathways i.e. through roots and foliage out of which root uptake was the dominant pathway. In the present study we focus on the root uptake. No visible impact of increased concentration of heavy metal was observed on the studied plant this may be due to resistance mechanism of the plant. Sites with higher pollution reported a low diversity of flora and fauna indicating the disturbance in their natural life cycle due to increasing pollution. On the basis of present study we can recommend that these palnts should be planted along river side as they were found resistant to heavy metal pollution.

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