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Impact assessment of contaminated River Yamuna water irrigation on soil and crop grown in peri-urban area of Delhi-NCR

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Abstract

Yamuna is the main river for the water resources and irrigation purposes in the National Capital region Delhi. The whole Yamuna pusta region is occupied for agricultural practices. In the present study, water, soil and crop of Yamuna has been collected from 15 different sites of Delhi at regular interval and analysed for the heavy metals name of Cu, Cr, Cd, Ni, Pb, Zn and various physico- chemical properties. There is a high significant correlation found between Copper-Lead, Copper –Zinc, Copper-Nickel, Nickel-Lead and Lead-Zinc. The metal contamination was found very high in the soil situated near Yamuna irrigated with irrigation water having heavy metal contamination. The metal got accumulated in soil and then bio accumulated by the crops grown on the contaminated agricultural field.

Key Words: ***Metal Pollution, HRI, Bioaccumulation factor, Yamuna.***

Introduction

Rivers are the most important freshwater resources, along the banks of which our hoary civilizations have flourished, and still, number of activities is dependent upon them. River water finds multiple uses in every sector i.e. agriculture, industry, transportation, aquaculture, public water supply etc. (Ravindra *et al.,* 2003). As we know that, from old times, rivers have also been used for cleaning and disposal purposes. High amount of waste from industries, domestic sewage and agricultural practices find their way into rivers, resulting in large scale deterioration of the water quality (Cosgrove *et al.,* 2014; Bhutiani *et al.,* 2018a; Bhutiani *et al.,* 2018b). The growing problem of degradation of our river ecosystem has necessitated the monitoring of water quality of rivers to evaluate their production capacity, utility potential and to plan restorative measures. (Kumar, 2012; Lalparmawii *et al.,* 2012) In Present study Yamuna river water quality monitored. Yamuna , originating from the Yamnotri glacier near Banderpunch peak of the lower Himalayas (38˚59'N 78˚27'E) in the Mussoorie range, at an elevation of about 6,320 m above mean sea level in the Uttarkashi district of Uttarakhand, India.(Sehgal *et al.,* 2012) Yamuna's catchment area of the Delhi is 1% of the river's total catchment area, but contributes more than 50% of the pollutants found in the Yamuna (Kaushik *et al.,* 2012; Prashar *et al.,* 2012). Yamuna, with an annual flow of about 10,000 m^3 and usage of 4,400 m^3, accounts for more than 70% of Delhi's water supplies (Husain, 2014). Moreover, the river serves as a source of irrigation for major stretches of agricultural fields that exist around its course (Varghese *et al.,* 2011). Due to partially unplanned industrial development in the city and its adjoining areas leading to increased population pressure, and adding loads of contaminants to the river ecosystem (Corcoran *et al.,* 2010). Yamuna leaves Delhi at Okhla barrage, by then, laden with the city's biological and chemical wastes, its water is dark brown/black in colour (Sehgal *et al.,* 2012). The concentration of micro-pollutants such as heavy metals, namely, Fe, Ni, Pb, Cd, cobalt (Co) and Cu in the various canals originating from River Yamuna in Haryana has been reported to exceed the maximum permissible limits for drinking (Indrajit Sen *et al.,* 2011). The heavy metals move through the aquatic food chain, and when polluted water is used for irrigation, it can lead to serious toxic effects on growth and yield of crops (Ali *et al.,* 2013). Heavy metals are a

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major concern because of their persistent and bio-accumulative nature (Li *et al.,* 2008). These metals may be of geological origin that enter the river system by weathering and erosion or anthropogenic in nature due to mining, industrial processing, agricultural run-off and sewage disposal (Förstner *et al.,* 2012). In the aquatic system, removal of heavy metals from the water to sediments may occur by settling particles; while some of these pollutants can be mobilized by accumulating into the biota from the sediments sink (Salomons *et al.,* 2012; Steele *et al.,* 2010). The present study was undertaken to assess the level of concentration of heavy metals cadmium (Cd), nickel (Ni), zinc(Zn), copper(Cu),lead (Pb), and chromium (Cr), in the Delhi segment of the Yamuna and the soil from agricultural fields irrigated by the river water. Some of these metals (Cd, Cr, Cu, Ni and Pb) are of major interest in bio-availability studies, as listed by the US Environmental Protection Agency (EPA). Other sources of environmental exposure are household dust, ceramic pottery, soldered cans, herbal medicine, lead paint, peeling paint, surface soil, plumbing system, batteries, municipal wastes and so on (Nduka *et al.,* 2015). Impacts of contamination of heavy metals on animal and human health include muscular weakness, lower score in psychometric tests and symptoms of peripheral neuropathy (Hussain *et al.,* 2012). Breathing problems and motor nerve conductivity have been noted in occupationally exposed populations. Some heavy metals are also considered as human carcinogens. Environmental exposure to these heavy metals over an extended period of time may lead to adverse effects, and intensive efforts are needed to explore this relationship as well as contain the levels (Karalliedde *et al.,* 2012). Other parameters like BOD, COD, DO, carbonates-bicarbonates, Sulphates, Sodium, SAR, RSC etc. has been studied to check the water quality in respect to Irrigation. Studies on the uptake of heavy metals by plants have shown that heavy metals can be transported passively from roots to shoots through the xylem vessels (Mapanda *et al.,* 2007). In addition, plant organs such as fruit and seed that have low transpiration rates (e.g. fruits and seeds) did not accumulate heavy metals because the storage organs are largely phloem-loaded and heavy metals are poorly mobile in the phloem, found that the concentrations of heavy metals in vegetables per unit dry matter follows the order: leaves > fresh fruits > seeds (Addo, 2014). Contamination of the human food chains by heavy metals is not directly affected by the plants total uptake, but rather by the concentration in those parts that are directly consumed.

Materials and Method

Study area

Delhi is situated in north India, 160 km south of Himalayas at latitude 28˚36′N, and longitude 77◦12′ E, at an altitude of 216 m above sea level. (NGJI, 2008) The fifteen different sites (Palla, Christian ashram, Jagatpur, Sonia Vihar, Wazirabad, Shastri park, Indraprastha, Okhla, Noida, Basantpur, Nehru vihar, Daryia nalla, Punjabi bagh, Keshopura and Nilothi of Yamuna pushta regions in Delhi-NCR was selected for the sampling along the stretch of Yamuna river in Delhi-NCR. This systematic sampling was adopted with a view to observe the contamination profile of agricultural fields along the river. The peoples and farmers of these places used the highly polluted water of Yamuna for the purpose of irrigation. (Fig. 1)

Sample collection and treatments

Water samples (100 ml) used for irrigation were collected in triplicate in a pre acid washed polypropylene bottle and 1 ml of concentrated HNO_3 was added in the water sample to avoid the microbial activity (Brhane *et al.,* 2014). These samples were brought back to the laboratory and kept in a refrigerator before digestion. Soil samples were collected in triplicate at different depths (0-15cm, 15-30cm and 30-45cm) and at varying distance (5m, 100m and 300m) from the river bank. Soil samples were air dried, crushed and passed through 2 mm mesh size sieve and stored at ambient temperature before analysis.(Singh *et al.,* 2010) Vegetables grown in the selected sites were collected, the details of different vegetables and crops analysed are mentioned in the Table 1. After collection the samples were identified and Packed into sterile polythene bags. In the laboratory samples were first cut in to pieces thoroughly washed with tap water following double distil water. The samples were then dried in an oven at 60ºC until constant weight obtained and grinded for

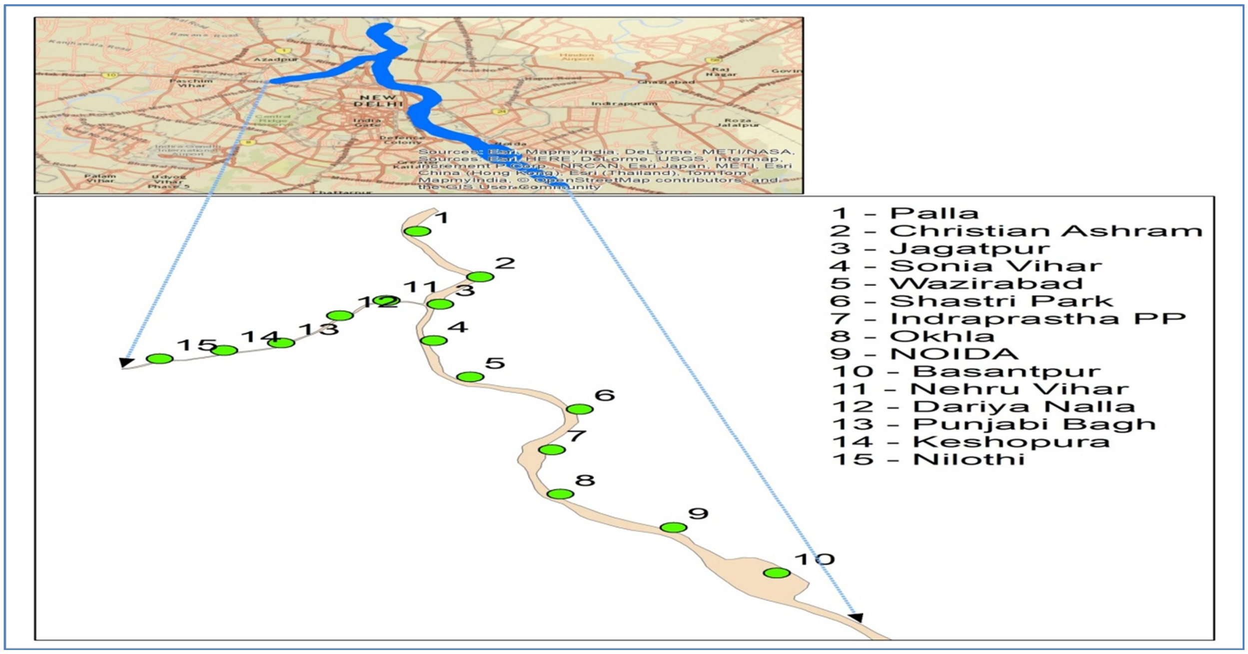

Fig. 1 Delhi –NCR Sampling sites

further analysis. Water, Soil and plant samples were collected from February 2013 to May 2014.

Digestion and Analysis of samples

Water samples (100 ml) were digested after adding 15ml of Di acid mixture (HNO_3 and $HClO_4$ in ratio 9:4) at 80ºC until a transparent solution was obtained (APHA, AWW &WEF, 2005). After cooling, the digested sample was filtered using Whatman no. 42 filter paper and the filterate was finally maintained to 100 ml with double distil water.

Soil (1 g) were digested after adding 15 ml of tri-acid mixture (HNO3, H2SO4, and HClO4 in 5:1:1 ratio) at 80 C until a transparent solution was obtained. After cooling, the digested sample was filtered using Whatman No. 42 filter paper and the filtrate was finally maintained to 25 ml with distilled water. The analysis was conducted using AAS4141 ECIL Atomic absorption spectrophotometer. The instrument was fitted with specific lamp of particular metal. The instrument was calibrated using manually prepared standard solution of respective heavy metals as well as drift blanks. Standard stock solutions for all the metals were obtained from Sisco research laboratories Pvt. Ltd., India. These solutions were diluted for the desired concentrations to calibrate the instrument. Acetylene gas was used as the fuel and air as the support. An oxidising lamp was used in all cases (Pal *et al.,* 2015). Plant samples (1g) were digested after adding 15ml of tri acid mixture (HNO_3, H_2SO_4 and $HClO_4$ in ratio 5:1:1 ratio) at 80ºC until a transparent solution was obtained .After cooling, the digested sample was filtered using Whatman no. 42 filter paper and the filterate was finally maintained to 25 ml with double distil water. Triplicate digestion of each sample was carried out together. The analysis was conducted using AAS4141 ECIL Atomic absorption spectrophotometer (Islam *et al.,* 2014).

Quality control analysis

Blank and drift standards (Sisco research laboratories Pvt. Ltd., India.) were run after five determination to calibrate the instrument. The coefficients of variation of replicate analysis were determined for different determinations for the precision of analysis and variations below 10% were considered correct.

Health Risk index

The health risk index was calculated as the ratio of estimated exposure of test vegetables and oral reference dose Oral reference doses were 4 $\times 10^{-2}$, 0.3 and 1×10^{-3} mg/day for Cu, Zn, and Cd respectively; 0.004, 0.02, 1.5 mg/day for Pb, Ni and Cr respectively Estimated exposure is obtained by dividing daily intake of heavy metals by their safe

Table 1. Samples collected from the 15 different sites of Delhi-NCR

Common Name	Scientific Name	Edible part
Cucumber	*Cucumis sativus*	**Fruit**
Rice	*Oryza sativa*	**Grain**
Bittergourd	*Momordica charantia*	**Fruit**
Lady finger	*Abelmoschus esculentus*	**Fruit**
Radish	*Raphanus sativus*	**Root**
Ridgegourd	*Luffa luffa*	**Fruit**
Red Spinach	*Basella alba*	**Shoot**
Mustard	*Brassica juncea*	**Shoot and Seed**
Wheat	*Triticum aestivum*	**Grain**
Spinach	*Spinacia oleracea*	**Shoot**
Carrot	*Daucus carota*	**Root**
Armenian Cucumber	*Cucumis melo*	**Fruit**
Pumpkin	*Cucurbita maxima*	**Fruit**
Bottlegourd	*Lagenaria siceraria*	**Fruit**
Sorghum	*Sorghum bicolor*	**Grain**
Beans	*Phaseolus vulgaris*	**Fruit**
Eddoe	*Colocasia esculenta*	**Root**
Cabbage	*Brassica oleracea*	**Shoot**
Pigweed	*Amaranthus palmeri*	**Shoot**
Brinjal	*Solanum melongena*	**Fruit**
Cauliflower	*Brassica oleracea*	**Inflorescence**
Tomato	*Solanum lycopersicum*	**Fruit**

Table 2. Water Quality Parameters as measured for the Yamuna River.

Parameters	Units	Methods
pH	pH unit	pH meter
Dissolved Oxygen	mg/l	Winkler azide method
Electrical Conductivity	millisiemens	EC meter
Calcium-Magnesium	mg/l	Versenate titration method
Chloride	mg/l	Mohr's titration method
Bicarbonates	mg/l	Sulphuric acid titration method
Sulphates	mg/l	Turbidimetric method
Sodium	mg/l	Flame photometer
Sodium Adsorption ratio	-	-
Residual Sodium carbonates	-	-
Heavy metals	ppm	Atomic Absorption Spectrophotometer

limit. An index more than 1 is considered as not safe for human health.(Grunert *et al.,* 2010) The required amount of vegetables in our daily diet must be 300 to 350 g per person has been suggested by WHO guideline.(Xue *et al.,* 2014) A survey of 100 people was done for the average daily vegetable intake rate having an average weight of 70 Kg. The average body weight was taken as 70 kg for adults according to World Health Organisation.

Bioaccumulation Factor

$$BAF = C_{shoot} / C_{soil}$$

C_{shoot} and C_{root} are metal concentration in the plant shoot (edible part) mg/kg and soil (mg/kg), respectively. BAF was categorised further as hyper accumulators, accumulators and excluder to those samples which accumulate metals >1 mg/kg, <1 mg/kg respectively (Zeng *et al.,* 2011).

Table 3. Mean Concentration of metal in the river Yamuna in different months.

Sites	Copper (ppm) (Mean±SE)	Chromium (ppm) (Mean±SE)	Nickel (ppm) (Mean±SE)	Lead (ppm) (Mean±SE)	Zinc (ppm) (Mean±SE)	Cadmium (ppm)
Palla	0.05±0.01	0.20±0.09	0.09±0.03	0.74±0.21	0.18±0.05	>0.01
Christian Ashram	0.11±0.06	0.23±0.15	0.13±0.03	0.49±0.19	0.14±0.05	>0.01
Jagatpur	0.12±0.05	0.27±0.13	0.14±0.04	0.50±0.15	0.20±0.08	>0.01
Sonia Vihar	0.05±0.01	0.16±0.07	0.07±0.03	0.65±0.23	0.16±0.06	>0.01
Wazirabad	0.10±0.04	0.04±0.02	0.05±0.01	0.52±0.21	0.18±0.06	>0.01
Shastri Park	0.09±0.05	0.03±0.01	0.04±0.01	0.51±0.18	0.19±0.079	>0.01
IP power Station	0.09±0.04	0.15±0.06	0.09±0.02	0.58±0.2	0.20±0.09	>0.01
Okhla	0.06±0.02	0.05±0.03	0.04±0.007	0.67±0.21	0.10±0.05	>0.01
Noida	0.04±0.01	0.10±0.04	0.05±0.01	0.53±0.20	0.08±0.04	>0.01
Basantpur	0.11±0.06	0.09±0.06	0.08±0.01	0.52±0.17	0.15±0.06	>0.01
Nehru Vihar	0.17±0.08	0.25±0.14	0.16±0.03	0.72±0.24	0.28±0.06	>0.01
Daryai Nala	0.09±0.03	0.02±0.01	0.04±0.01	0.77±0.25	0.44±0.2	>0.01
Punjabi Bagh	0.38±0.25	0.17±0.10	0.23±0.06	0.97±0.54	0.76±0.47	>0.01
Keshopur	0.09±0.04	0.04±0.02	0.05±0.01	0.87±0.28	0.38±0.13	>0.01
Nilothi	0.09±0.03	0.08±0.04	0.05±0.01	0.93±0.32	0.22±0.07	>0.01
Permissible Limit(ppm)	0.2	0.1	0.2	5	2	0.01

Table 4. Correlation between heavy metals in Water.

Heavy metal in water ($p < 0.05$)	***Copper***	***Chromium***	***Nickel***	***Lead***	***Zinc***
Copper	1	0.27481	0.46076	0.83949	0.86673
Chromium		1	-0.1236	-0.0133	0.04829
Nickel			1	0.715	0.47361
Lead				1	0.8153
Zinc					1

Table 5. Correlation between heavy metals in Soil.

		Depth 0-15			
Heavy metal in Soil ($p < 0.05$)	*Copper*	*Chromium*	*Nickel*	*Lead*	*Zinc*
Copper	*1*	*0.53388*	*0.364449*	*0.409893*	*0.724147*
Chromium		*1*	*0.448508*	*0.551098*	*0.790035*
Nickel			*1*	*0.653633*	*0.671749*
Lead				*1*	*0.78512*
Zinc					*1*
Depth 15-30					
Heavy metal in soil ($p < 0.05$)	*Copper*	*Chromium*	*Nickel*	*Lead*	*Zinc*
Copper	*1*	*-0.38276*	*0.347255*	*0.467941*	*0.052227*
Chromium		*1*	*0.232785*	*-0.26213*	*0.116423*
Nickel			*1*	*0.746727*	*0.739548*
Lead				*1*	*0.58861*
Zinc					*1*
Depth 30-45					
Heavy metal in soil ($p < 0.05$)	*Copper*	*Chromium*	*Nickel*	*Lead*	*Zinc*

Copper	*1*	*-0.27394*	*-0.11895*	*0.072371*	*-0.17879*
Chromium		*1*	*0.85716*	*0.343873*	*0.538814*
Nickel			*1*	*0.494751*	*0.551806*
Lead				*1*	*0.777835*
Zinc					*1*

Table 6. Bioaccumulation of metal from soil to crop.

	Copper	Chromium	Nickel	Lead	Zinc
Cucumber	3.81	1.46	3.15	1.02	4.15
Rice	3.35	1.44	2.94	0.52	3.23
Bittergourd	4.18	1.63	0.74	2.45	3.27
Lady finger	3.28	0.60	2.19	4.81	1.91
Radish	2.58	1.94	2.55	1.11	2.55
Ridgegourd	3.57	2.66	1.49	2.26	2.07
Red Spinach	0.38	4.99	3.59	1.47	4.50
Mustard	1.87	1.01	2.35	2.62	1.79
Wheat	1.88	1.49	1.65	1.62	2.72
Spinach	1.56	0.67	3.38	1.62	3.96
Carrot	2.24	1.76	0.81	3.28	3.41
Armenian Cucumber	3.13	4.07	1.93	1.97	1.87
Pumpkin	0.73	0.29	1.98	1.65	4.46
Bottlegourd	3.69	2.71	2.80	1.87	2.28
Sorgham	1.99	0	0.54	1.51	2.64
Beans	0.40	0.01	1.88	1.58	4.27
Eddoe	2.64	0.30	0.23	0.76	0.74
Cabbage	2.51	0.23	2.58	1.92	1.56
Pigweed	3.49	0.00	2.03	2.43	4.67
Brinjal	3.30	0.00	2.89	2.86	4.36
Cauliflower	0.37	0.54	3.60	1.81	0
Tomato	3.95	0.45	2.14	0.89	4.96

Results and Discussion

River water Samples

The concentration of metals in river water samples at different sampling point with monthly variation are shown in Table 3.

From the above table we can able to conclude that the Chromium in most of sites above the permissible limits while copper and nickel at specific sites above the limits. But the concentration of all the metals has been detected near to the permissible limits which pointed out that the in coming years it will raise above the limits if the industrial and other pollutants continuously discharging in the river. The sites where concentration above the limits in case of copper and Nickel was Punjabi bagh, while in case of chromium Palla, Christian ashram, Jagatpur, Sonia Vihar, IP power station, Noida, Nehru Vihar and Punjabi bagh. All other metals except these three are below permissible limits. Average concentration of metals in river water in order Pb>Zn>Cr>Ni>Cu.

The range of pH in river water samples is between 7.2 to 8.3 implies that the water is neutral to slightly alkaline. If the pH value is acidic then there is increase in bioavailability of heavy metals (Singh *et al.,* 2010). The electrical conductivity of water varies from 0.2 to 1.7 mS (Lozba-Ştirbyleac *et al.,* 2011) and dissolved oxygen (Parker *et al.,* 2010) 0.1 to 8 mg/l in river water samples at different sampling sites. Concentration of calcium and magnesium in river water ranged from 83.2 mg/l to 524.8 mg/l. Concentration of chloride ranges from 112 mg/l to 574 mg/l. Concentration of bicarbonates in river water ranged from 97.6 to 536.8 mg/l. Sulphates 7.7 to 1.94 mg/l. Sodium from 195.2 to 11.27 mg/l. Sodium absorption ration starts from 0.414 to 4 and the Residual sodium carbonates -0.4 to -5.4 in river water.

Sehgal *et al.* (2012), studied the Yamuna river water and was found out that the Average heavy metal concentration at different locations in river water were in the order of Fe>Cr>Mn>Zn>Pb>Cu>Ni>Hg>As>Cd (Rai *et al.,* 2011; Sehgal *et al.,* 2012). Examination of correlations between metal levels in water [33] showed high significant correlation between Copper-Lead , Copper –Zinc, Copper-Nickel, Nickel-Lead and Lead-Zinc. This suggested the possibility of similar sources of these heavy metals. Similar correlation was not seen in chromium and other metals, thereby suggestive of different sources of contamination (Table-4).

Soil Samples

In soil samples, the sampling has been performed at 10, 100 and 300 meter from the bank of river towards the agricultural field at different sites of Delhi-NCR. On studying, the concentration of Copper 5.8 to 62.3 ppm at 10 meter distance from the bank of river Yamuna. At 100 meter the concentration ranged from 7.1 to 42.1 ppm and at 300 meter from the Yamuna River the concentration ranged from 0.4 to 44.007 ppm. In the 10 meter distance from the river, the concentration was found highest in Nilotic, Nehru Vihar and Shastri Park (Fig.2 - 9). Concentration of Chromium at 10 meter distance from the bank of river ranged from 17.1 – 81.6 ppm, at 100 meter ranged from 10.1 – 73.6 ppm and at 300 meter ranged from 0.002 – 47.1 ppm. Chromium concentration highest in following places Punjabi bagh and shastri park (Fig.2 - 9).

Concentration of lead ranged from 10.8 -29.3 ppm at 10 meter distance from the bank of river. At 100 meter distance ranged from 9.1 -25.8 ppm and at 300 meter ranged from 0.6 -33.1 ppm. Lead concentration highest in Nilothi and Keshopura (Fig.2 - 9).

Concentration of Nickel at 10 meter distance ranged from 7.7 -20.9 ppm, at 100 meter ranged from 6.4 -19.3 ppm and at 300 meter ranged from 0.44 -16.4 ppm. The concentration of Nickel highest in Nilothi, Nehru vihar and Sonia vihar (Fig.2 - 9).

Concentration of Zinc at 10 meter distance from the river Yamuna ranged from 18.5 -49.2 , at 100 meter distance ranged from 13.5 – 55.6 ppm and at 300 meter ranged from 0.69- 39.08 ppm. Concentration of zinc found highest at Punjabi Bagh , Nehru vihar and Shastri Park (Fig. 2 - 9).

So, at 10 meter distance from river bank the average concentration of metals in order Zn>Cr>Cu>Pb>Ni at 0-15cm and 15-30 cm depth. At 100 meter from river bank, the average concentration of metals in order Cr>Zn>Cu>Pb>Ni (0-15cm depth and 15-30 cm depth) while at 30-35 cm depth the order was came Cr>Zn>Pb>Cu>Ni. At 300 meter from the river bank the average concentration of metals in order Cr>Zn>Pb>Cu>Ni (0-15 cm depth) while at 15-30 and 30-45 cm depth the order was came Zn>Cr>Pb>Cu>Ni. The concentration of all the studied heavy metals in soil was below the permissible limits recommended by the European Union standards (2006) and Indian Standards Awasthi(2000) the standards are the following Copper-100 ppm, Chromium 100 ppm , Nickel 50 ppm, Lead 100 ppm and Zinc 300 ppm.

Sehgal *et al.* (2012), were reported the concentration of heavy metals (Cd, Ni, Zn, Fe, Cu, Mn, Pb, Cr, Hg and As) in the waters of River Yamuna and in the soil of agricultural fields along its course in Delhi from 13 sites, spread through the Delhi stretch of Yamuna, starting from the Wazirabad barrage till the Okhla barrage. They were found out that the average heavy metal concentration at different locations in river water were in the order of Fe>Cr>Mn>Zn>Pb>Cu>Ni>Hg>As>Cd.

Contamination in soil at sampling locations showed lesser variation than water samples, thereby

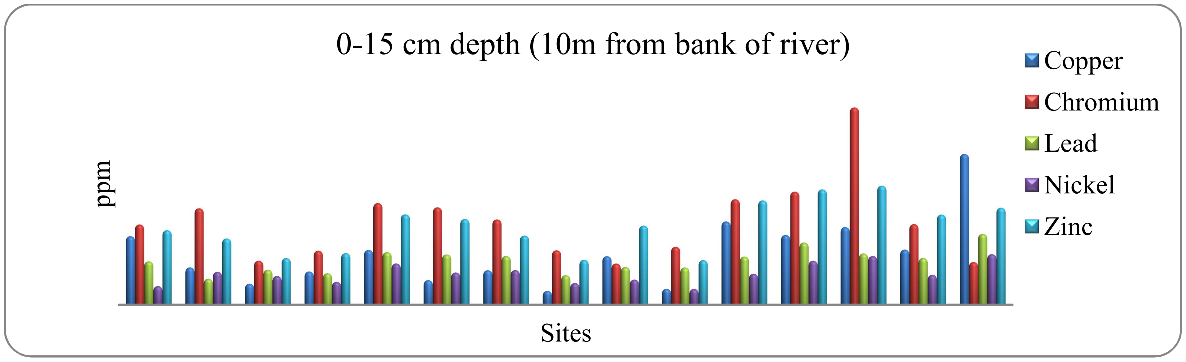

Fig 2. Metal concentration in soil 0-15cm depth (10m from bank of river).

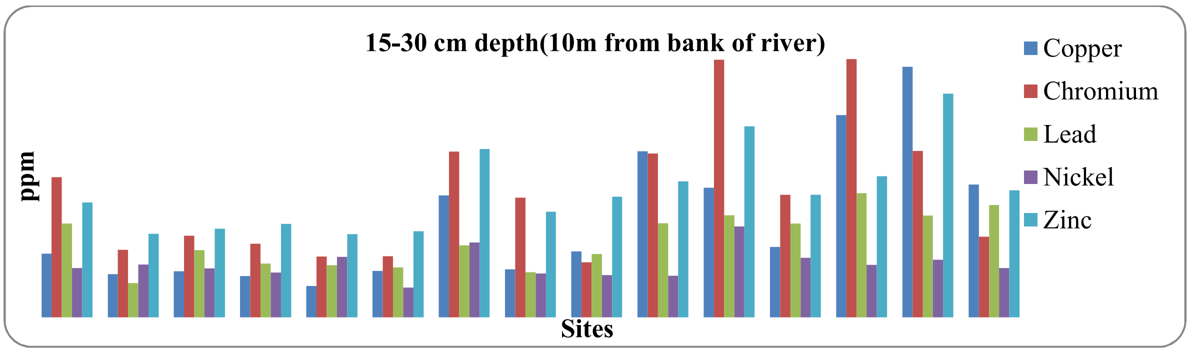

Fig 3. Metal concentration in soil 15-30cm depth (10m from bank of river).

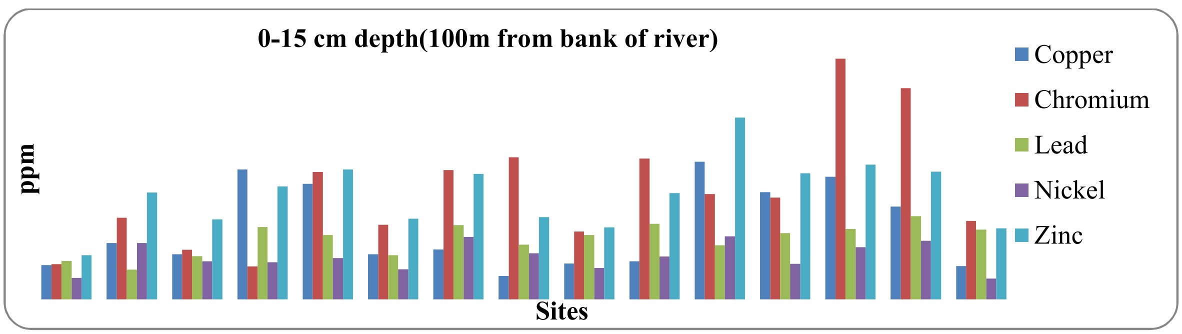

Fig 4. Metal concentration in soil 0-15cm depth (100m from bank of river).

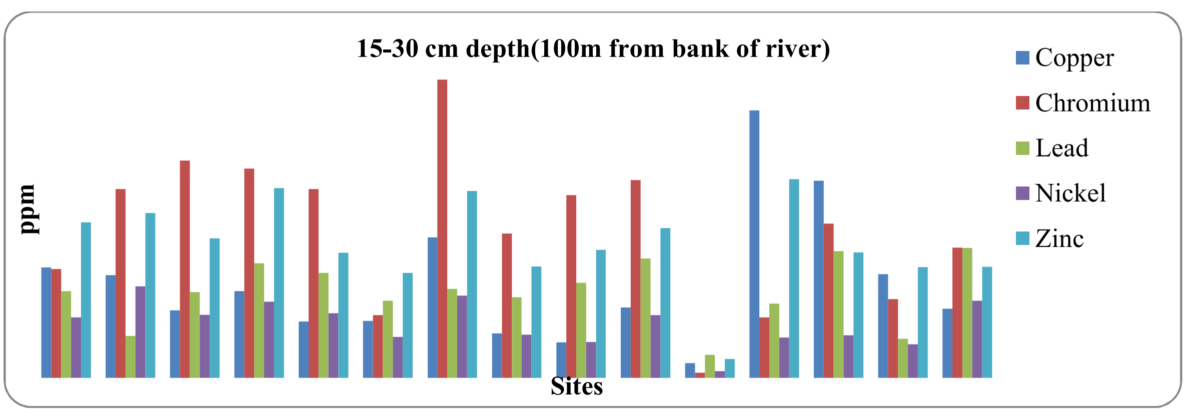

Fig 5. Metal concentration in soil 15-30cm depth (100m from bank of river).

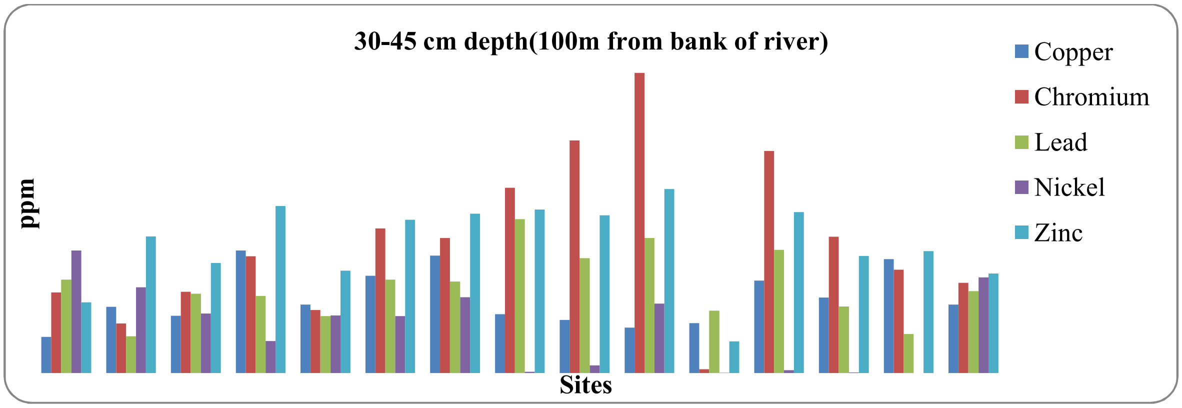

Fig 6. Metal concentration in soil 30-45 cm depth (100m from bank of river).

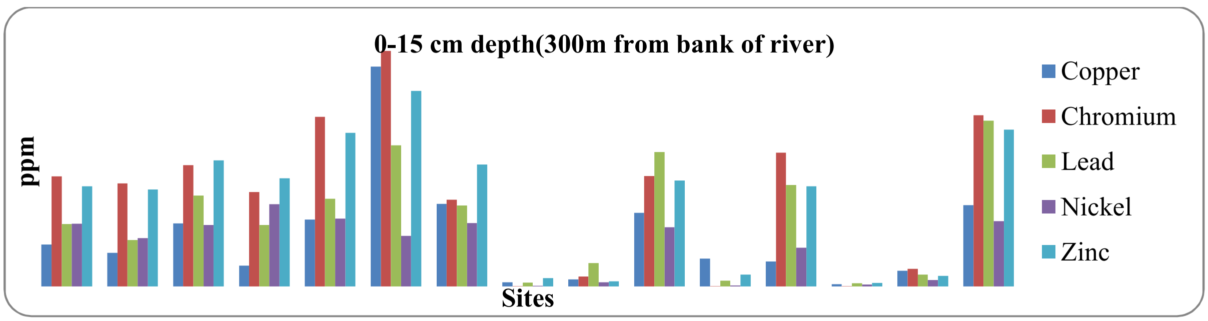

Fig 7. Metal concentration in soil 0-15 cm depth (300m from bank of river).

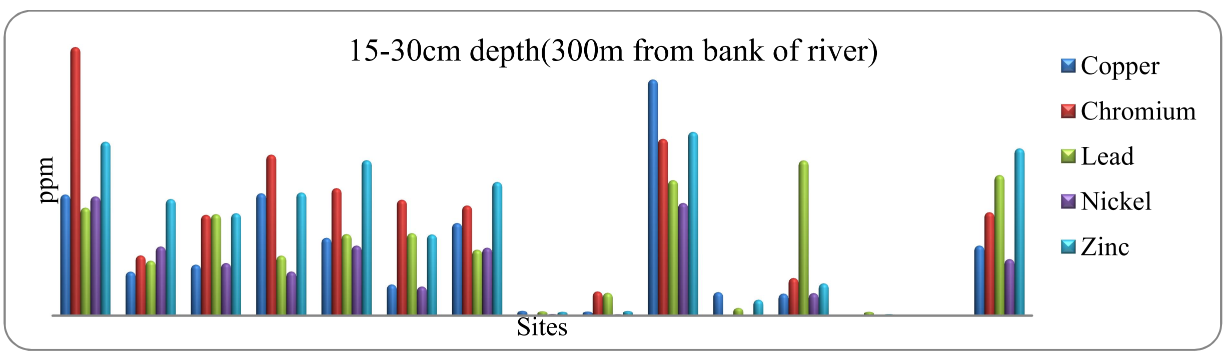

Fig 8. Metal concentration in soil 15-30cm depth (300m from bank of river).

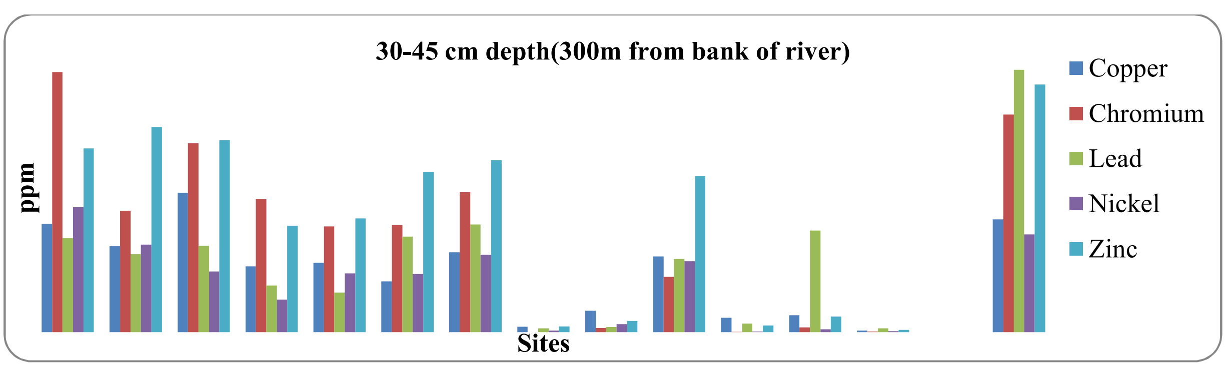

Fig 9. Metal concentration in soil 30-45cm depth (300m from bank of river).

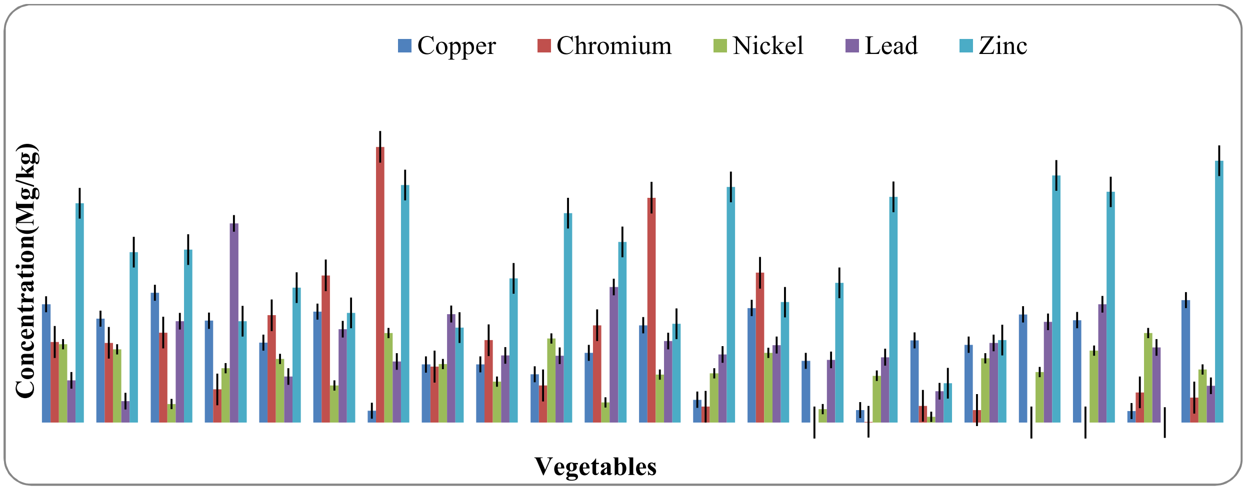

Fig 10. Variation of heavy metals (Cu,Cr,Ni,Pb,Zn) in different vegetables

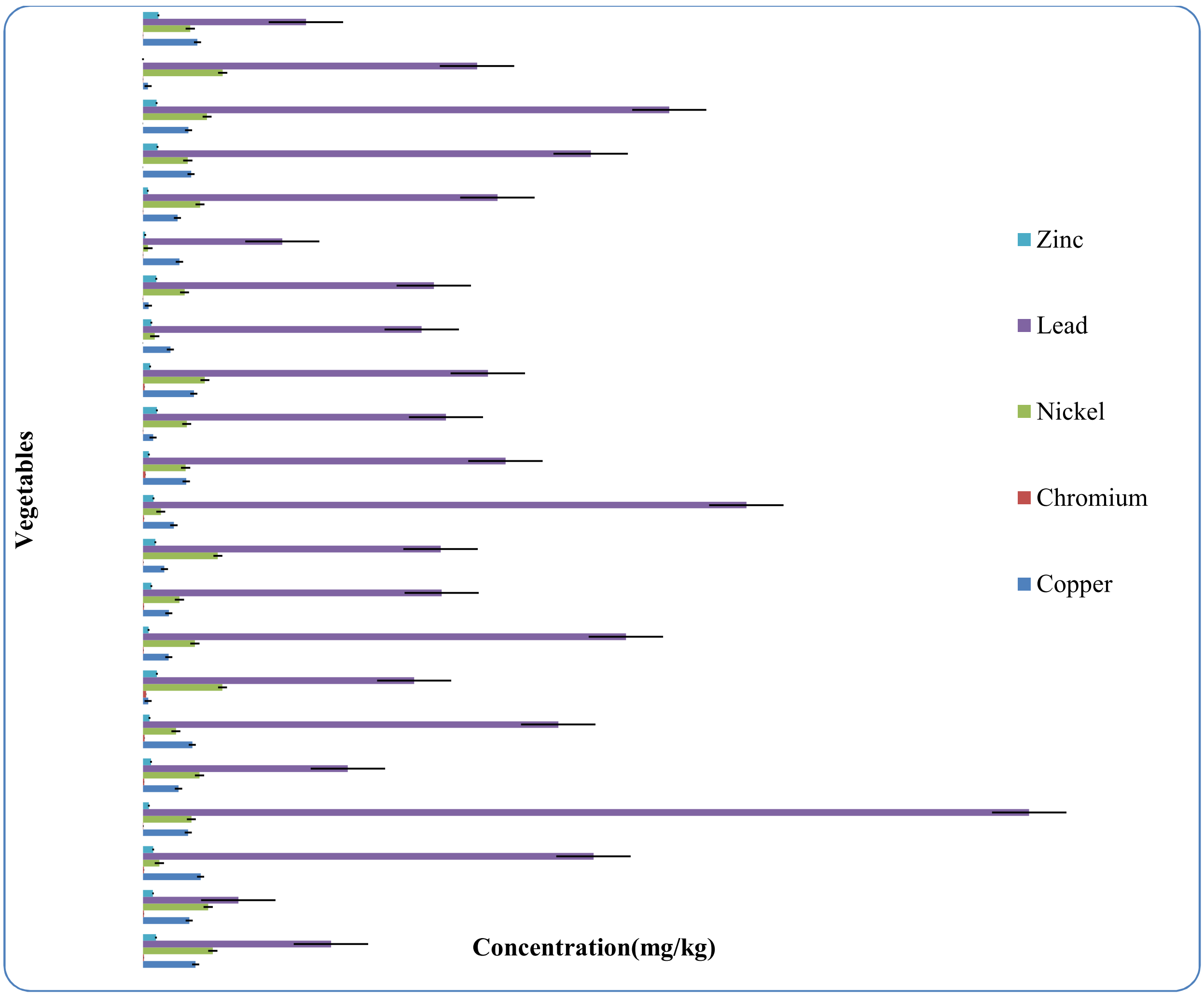

Fig 11. Variation in HRI (Health Risk Index).

suggesting deposition over long periods of time. Cadmium was found to be below detection limit at all locations.Copper levels ranged from 9.3–36.45 mg/kg in soil, Zinc levels ranged from 31.9 to 136.85 mg/kg in soil, Lead levels ranged from below detection limitto 114.6 mg/kg, Levels of hexavalent chromium (Cr-VI) in soil samples at different locations ranged from 4.52 mg/kg to 35.29 mg/kg. Overall, the mean heavy metal concentration at different locations in soil was found to be in the following order Fe>Mn>Zn>Cr>Pb>Ni> Hg>Cu>As>Cd (Sehgal *et al.,* 2012). Examination of correlations between metal levels in soil at different depth showed high significant correlation between Copper-Lead, Copper –Zinc, Nickel-Zinc, Nickel-Lead and Lead-Zinc. Chromium- Lead good correlation was also found but at depth (0-15) only in soil. This suggested the possibility of similar sources of these heavy metals. Similar correlation was not seen in chromium and other metals, thereby suggestive of different sources of contamination. (Table-5)

Plant Samples

Due to use of metal contaminated water i.e. Yamuna river water and wastewater for the irrigation purpose, the metal got accumulated in soil and then by vegetables grown in that contaminated soil. Which ultimately taken up by humans. The concentration of heavy metals showed variation among the different vegetables and crops collected from the fifteen different sites. Concentrations of heavy metals (Cu,Cr,Cd,Ni,Pb,Zn) in vegetables and crops . The difference in heavy metals concentration in different vegetables may be described to the difference in the morphology and physiology for heavy metals uptake, exclusion, accumulation and retention (Gupta *et al.,* 2013). For all six metals, the value of copper, chromium and zinc found uneven with different crops and vegetables. The value of nickel and lead found more than the permissible limits in each and every vegetable grown in the Yamuna puhsta region. Cadmium was not detectable in all the sampled vegetables and crops. The concentration of copper has ranges from 3.8 - 42.7 mg/kg. The amount of copper was maximum in Bitter gourd and minimum in Cauliflower. Copper is an essential element for normal biological activities and also helpful in the enzymatic activities of biological system. The tyrosinase and aminooxide enzymes are regulated through the copper but in adequate quantity (Nordberg *et al.,* 2013). Excessive intake of copper leads to hemolysis, hepatoxicity and nephrotoxicity (Wambu *et al.,* 2016). According to an estimate only 1.5-3 mg/day copper has been determined safe for human consumption. In case of chromium the highest concentration was detected in Red spinach (90.7mg/kg) and lowest in Beans (0.23mg/kg). The daily intake of chromium is 50 to 200 µg/day, has been suggested by US national Academy of Science (Olawoyin *et al.,* 2012). For Zinc, the maximum concentration found in tomato (86.2mg/kg) and minimum concentration in eddoe (12.9mg/kg). Zinc is important for the enzymatic function. Zinc plays an important role in synthesis of protein, DNA and insulin. It is second most abundant element in human next to iron. The recommended dietry intake of zinc is 15mg/day for adult (Sharif *et al.,* 2012). And for pregnant woman its 30mg/day. Nickel and Lead was found above the permissible limits in all vegetables and crops. The maximum concentration of nickel found in red spinach and Cauliflower (29.4mg/kg) and minimum in Eddoe (19mg/kg).Nickel is known to be responsible for heart attacks, depression, haemorrhages, cancer and low blood pressure (Lokeshappa, *et al.,* 2012). On the other hand, the maximum concentration of lead found in Ladyfinger (65.5mg/kg) and minimum in rice(7.05mg/kg).Long term exposure of lead leads to damage the brain ,kidneys and ultimately cause death. The concentration of metals accumulation was found more in vegetables in respect to cereals crops (Sörös *et al.,* 2012). All the 22 samples accumulate metal but 4 samples i.e. Brinjal, Bittergourd, Rice and Cucumber accumulate all the studied metals more than the permissible limits (Fig.10). The metal accumulation is depends on plants physiology but the nature of metal binding efficiency of different metals is also one of the reason of difference in the uptake of metal by plants.

Health risk index

The health risk index of metals (Cu,Cr,Cd,Ni,Pb,Zn) of 22 vegetables shows that the copper, chromium ,Cadmium ,Nickel and Zinc for all types of vegetables are lower than 1. (Fig. 11)

The health risk index of Lead was higher than 1, which poses greater risk of health for consumers. Except rice all other 21 studied crops have health risk index more than 1 in case of lead. This indicates that high HRI value crops had great potential to health hazards. Earlier, it is reported that the lead, Cadmium and Zinc found more than 1 HRI value in some vegetables in area around Dinapur sewage plant, India. Also, Cui *et al.* (2004), studied the vegetables of area Nanning, China and studied the risk of Cadmium and Lead through consumption of vegetables. Jolly *et al.* (2013), studied the Rooppur, Bangladesh area and find out more than 1 HRI of vegetables with metals Lead, Zinc and Cadmium.

Bioaccumulation factor

The bioaccumulation factor in most of the crops of Delhi-NCR regions above 1 , which suggested that the accumulation of metals from soil to edible part of plants is in positive way and if increase in the concentration in soil the bioaccumulation of metal also increases (Liu *et al.,* 2012) (Table 6).

Conclusion

The concentration of metals in the river water samples i.e. Copper in Punjabi bagh (0.38ppm) , Chromium in Palla (0.20ppm), Christian Ashram(0.23ppm), Jagatpur (0.27ppm) , Sonia Vihar (0.16ppm), IP Power Station (0.15ppm), Noida(0.10ppm) , Nehru Vihar(0.25ppm) and Punjabi Bagh (0.17ppm) and Nickel in SoniaVihar (0.21ppm), Wazirabad (0.21ppm), Shastri Park (0.22ppm), IP Power Station (0.26ppm), Okhla (0.24ppm), Noida(0.23ppm), Nehru Vihar (0.21ppm), Daryia Nalla (0.25ppm) and Punjabi Bagh (0.69ppm). The concentration of metal in soil below the limits but near to the permissible range which suggest that in near future it will increase if metal polluted water continuously used for irrigation. Examinations of correlation between different heavy metals in water and soil suggested that Copper, zinc, Nickel and lead are highly connected and thereby suggestive of different sources of contamination. The concentration of Health risk index for copper, chromium, nickel and zinc was less than 1 but for lead except rice all other 21 Crops shows HRI value more than 1.

The overall study concludes that the metal accumulation in crops is quite high. The main cause of metal contamination is use of industrial grey and wastewater which is highly contaminated with metal .The more contaminated water of irrigation the more concentration of metal in that soil and then to vegetables and to humans. Moreover it is suggested that the irrigation water used should be treated well before using it in the field. For the treatment of water some biological agents used to make the system eco friendly. As these metals accumulation in the vegetables can be toxic to the consumers when they are present in excess or cause metal related diseases when present in high quantities which are not suitable for the human health.

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