Assessing Soil Quality due to Industrial Pollution in Yamuna Nagar of Haryana; India

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Abstract--In major industrial areas, soil gets contaminated by the industrial activities. The main focus of this study was to assess the soil quality in vicinity of three selected industries (sugar mill, paper mill and thermal power plant) and along Western Yamuna Canal (WYC) located in Yamuna Nagar District of Haryana state, India. The changes in pH, EC, Ca, Mg, Na, K and heavy metals (Cu, Cr, Cd, Mn and Ni) were observed in summer and winter seasons of three years (2009-2012). The concentration of EC, salinity and potassium were found to be higher in vicinity of paper mill soil samples followed by sugar mill and thermal power plant. However, concentration of sodium, calcium and magnesium were higher in sugar mill vicinity soil samples followed by paper mill and thermal power plant. Higher concentrations of heavy metals (Cr, Ni, Cu) were generally present in paper mill vicinity soil samples. EC, salinity, Na, Ni and Mn exhibited a significant positive correlation among themselves in vicinity of industrial soil samples. In vicinity of WYC all studied parameter of soil samples exhibited a highly significant positive correlation with each other except with pH. Significant seasonal variations were observed in soil samples in vicinity of industries and WYC; and significant variations among sites were also observed in WYC vicinity soil samples. The results obtained definitely indicate that effluents and other waste materials from the paper mill and sugar mill have contributed to significant alteration of soil quality in the vicinity of the mills and the natural soil composition has been affected similar to surface and ground water quality.

Index terms- soil pollution, sugar mill, paper mill, thermal power plant, heavy metals, Western Yamuna Canal.

1 INTRODUCTION:

Soil is not only a medium for plant growth or pool to dispose of undesirable materials, but also a transmitter of many pollutants to surface water, groundwater, atmosphere and food [1]. Since antiquity, soil has been the repository of society's wastes [2]. The presence of any element in a fatal concentration in the soil could be due to both natural and anthropogenic factors; therefore it is often quite difficult to discriminate among the different causes. With the rapid urbanization, industrialization, and agricultural intensification, a large amount of pollutants are being discharged into the soil ecosystems [3]. Many industries in India discharge their untreated waste water on land or natural stream. This causes lot of physical, chemical and biological hazards of land and water. Due to discharge of effluents directly or after treatment soil of nearby industrial area get contaminated. Heavy metals constitute a main group of soil pollutants since their contamination in environment affects all ecosystem components [4]. Rapid industrialization has occurred in Haryana over last two decades. More than a thousand medium and large industries with a capital investment of Rs. 200 billion have been established in the state. Yamuna Nagar is the second biggest industrial town of Haryana. There are many industries such as, paper-mill, sugar mill, distillery, cement, metal industries, ply board etc. All the industries discharge their waste water into Western Yamuna Canal. The industrial effluents contain appreciable amounts of inorganic and organic chemicals and their by products. Hence in many places the pollution load discharged into the environment has exceeded the assimilative capacity and caused severe degradation of environment and ultimately affected the livelihood of the people. The problem of pollution is severe due to paper mill [5], sugar mill and thermal power plant [6], [7]. In the present study, therefore, an attempt was made to assess the impact of industrial effluents on soil in vicinity of sugar mill, paper mill, thermal power plant and along Western Yamuna Canal of Yamuna Nagar city. The physiochemical properties and heavy metals contamination in soil was assessed and seasonal variation were determined in this study of three years.

Study area

Yamuna Nagar is the second big industrial city located in north-eastern part of Haryana State and lies between 29º 55′: 30º 31′ north latitudes and 77º 00′: 77º 35′ east longitudes. Total geographical area of the district is 1756 sq.km and comprises 4% of total area of State (Fig. 1.1). Population explosion, uncontrolled urbanization and industrialization have caused a high rate of waste generation in Yamuna Nagar and Yamuna River. In the upper segment flowing through Poanta Sahib, Yamuna River reaches Hathnikund/Tajewala in Yamunanagar district of Haryana state, where the river water is again diverted into Western Yamuna Canal and Eastern Yamuna Canal for irrigation. The Western Yamuna Canal (WYC) command area is located between the north latitudes 28°20′ and 30º29′and east longitudes 75°48′ and 77°35′ and comprises the eastern, central and southern parts of the state of Haryana (Fig. 1.2). It has a geographical area of about 13,543 sq km, spread over 49 blocks in the districts of Karnal, Panipat, Sonepat, Rohtak and Jhajjar and partly in the districts of Hisar, Bhiwani, Jind, Yamunnagar, Gurgaon and Rewari. The total length of the WYC with all its branches is 325 km [8]. All domestic and industrial discharges from the Yamunanagar are let out into this canal.

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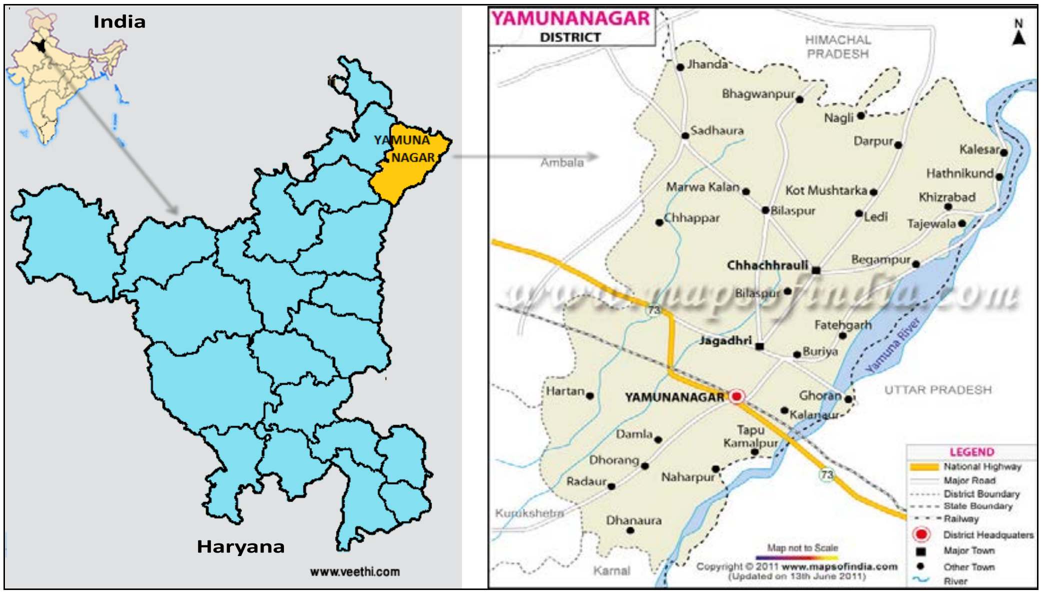

Fig. 1.1 Location map of study area

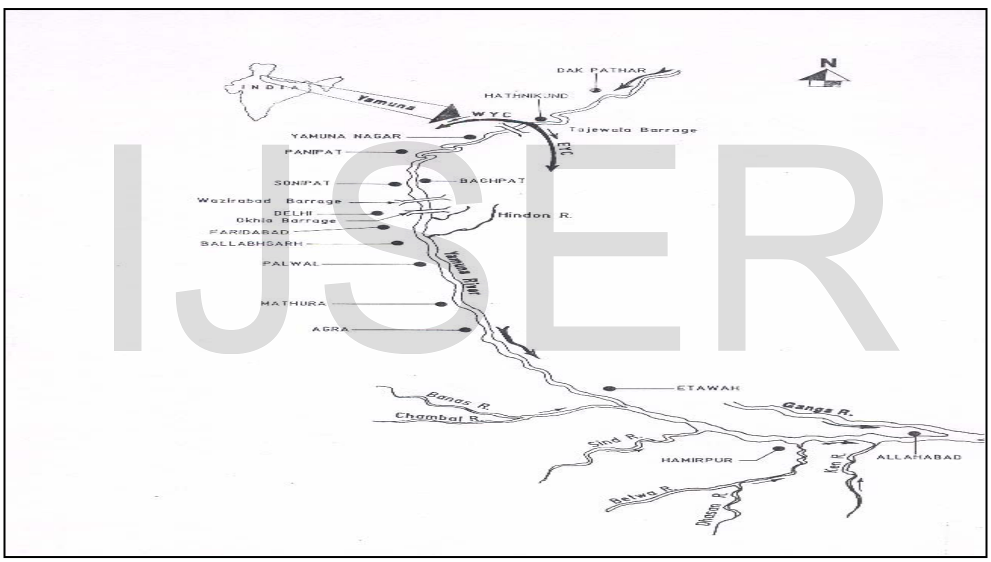

Fig. 1.2 Path of Yamuna River [9]

2 Materials and Methods

The sampling sites selected within the city were three industrial areas, i.e sugar mill (S.M), paper mill (P.M), thermal power plant (T.P.P) and along Western Yamuna Canal (W.Y.C) belt approximately 15 km stretch from Hamida Area Bridge to Buriya bridge. Sampling of soil was done in each summer and winter season in vicinity of selected industries and Western Yamuna Canal from June 2009 – January 2012. Nine sampling sites were selected for the collection of soil samples near industries, three from each industry named (SM, I-III), (PM, I-III), (T.P.P, I-III) within the 100 m periphery of each industry and 20 sampling sites were selected along Western Yamuna Canal (W.Y.C, 1- 20) approximately 500m apart (Fig. 1.3).

Soil samples were collected from each sampling location by using auger, and the soil samples were collected in self locking plastic bags. The selected depth of sampling was up to15 cm below the surface. In all 29 representative soil samples were collected from the selected study sites. Every precaution was taken to avoid contamination during sampling. The samples were stored at 4°C in the laboratory until they were analyzed, and the samples were dried at 60°C, sieved to remove particles >2 mm, and homogenized prior to analyses.

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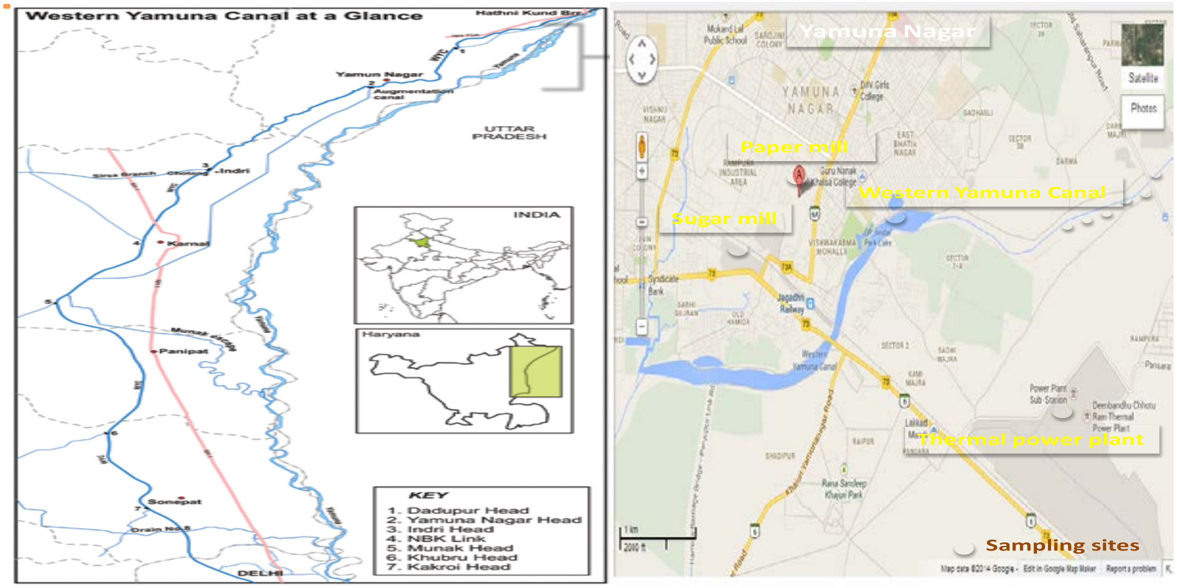

Fig. 1.3 Map of selected industries and Western Yamuna Canal

The samples were analyzed for physical and chemical characteristics. pH was measured using a pH meter Model 361 (Systronics µpH System). A digital conductivity meter (Model 61) was used for conductivity measurements. In both cases, (physical and chemical characteristic) 20 g of soil samples were weighed and suspended in 50 mL of distilled water and stirred before introducing probe. The samples taken for analysis of metals were acidified to pH<2 with analytical grade HNO3, and stored in HDPE plastic bottles until they were analyzed. Concentrations of heavy metals (Copper, Cadmium, Chromium and Manganese and Nickel) in soil samples were estimated by using Atomic Absorption Spectrophotometer (Shimadzu, AA - 7000) fitted with specific lamp of particular metal using appropriate drift blank. Carrier gas used was acetylene and outside and inside pressure of acetylene was 1.5 Bars and 0.921 Bars respectively. The standards of all the metals were provided by E. Merck, Germany. Three replicate was obtained to assess precision of the analytical techniques. The water samples taken for analysis of calcium, magnesium, sodium and potassium were not acidified; they were put in a refrigerator immediately after they were received in the laboratory, and kept at 4°C until they were analyzed. All water samples were filtered through 45 µm filters prior to analyses.

Means of triplicate readings obtained in study were subjected to analysis of variance (ANOVA). Standard deviation and standard error were determined by using MS excel spreadsheet. A correlation matrix test was carried out to check the significant relationship among physico-chemical parameters.

3 Results and Discussions

Mean concentrations of physiochemical parameters of soil samples in vicinity of industries and along WYC in summer and winter seasons of three years are summarized in Table 1.1 and 1.2.

Soil pH is important because it influences the availability and plant uptake of micronutrients including heavy metals [10]. The average mean pH range of soil samples in all six samplings (summer 2009 to winter 2012) ranged from 7.44±0.32 (S.M-II) to 8.17±0.72 (P.M-I) and 7.37±0.39 (WYC-12) to 8.13±0.43 (WYC-13) in vicinity of industries and WYC respectively (Table 1.1, 1.2). Soil samples from nearby paper mill were found to be little more alkaline (7.88) followed by thermal power plant (7.84) and sugar mill (7.73) soil samples. The large amount of sodium in the soil resulted in high pH of the soil samples closest to the industries. More alkaline pH of soil in vicinity of paper mill was also reported by [11]. Soil pH along WYC was mostly found above the normal range (6.5 to 7.6) as reported by [12]; clearly indicating that soil was slightly alkaline in nature. In vicinity of industries and along WYC pH values were found more in winter season compared to summer season, which might be due to decreased decomposition rate owing to reduced microbial activity and increased algal production [13]. The variations were estimated to be significant ($p<0.01$) among seasons for soil samples in vicinity of industries and WYC. However, no significant correlation of pH was observed with all studied parameters in industrial and WYC vicinity soil samples (Table 1.3, 1.4).

The variations in EC values found to be significant between all industrial and along WYC sites at ($p<0.01$) and ($p<0.05$) respectively. The highest average mean value of EC was noticed in paper mill industry vicinity soil (2.09 mS/cm) followed by sugar mill (1.66 mS/cm) and thermal power plant (0.30 mS/cm). The high values of EC at paper mill sites might be due to higher salt concentration of effluents in the soil close to the paper mill. Comparatively higher values of EC were found at WYC-1 and WYC-2 site in each sampling. The salt rich industrial effluents and sludge disposal on these sites are the possible reasons for highest soluble salt content in soil. Except pH, electrical conductivity of soil in vicinity of industries and along WYC exhibited significant positive correlation with all studied parameters (Table 1.3, 1.4). The variations were found to be significant ($p<0.05$) among seasons in WYC soil samples; whereas no significant variations among seasons were observed for industrial soil samples.

Across all seasons and sites higher average mean value of salinity in soil was found to be in P.M -III (1.50±0.32 PPT) (Table1.1) and WYC -2 site (1.17±0.26 PPT) (Table 1.2) in summer and winter season respectively. A very sharp decrease in salinity content with increase in distance from industries was observed in WYC soil sampling sites. The variations were observed to be significant among sites ($p<0.01$); and correlation of salinity with all studied parameter was also observed to be positively significant except with pH (Table 1.3, 1.4). Average mean value of salinity for all sites and seasons in vicinity of industries and WYC was found to be higher in summer season compared to winter season. Soluble salts move readily with water, and in summer evaporation moves salts to the soil surface and increase the salt accumulation in soil.

Sodium acts as a deflocculating agent and displaces the divalent cations like calcium, magnesium and cumulatively the soil losses its productivity. Soil permeability can be harmed by a high sodium concentration [14]. Average value of sodium was found to be little higher in sugar mill soil samples (60.15 mg/L) followed by paper mill (59.78 mg/L) and thermal power plant soil samples (21.54 mg/L). Sodium exhibited significant correlation with Cu ($r = 0.68$), K ($r = 0.71$), Mn ($r = 0.72$), Mg ($r = 0.77$), Ca and Ni ($r = 0.84$) EC ($r = 0.86$), and Salinity ($r = 0.93$) (Table 1.3). Along western Yamuna canal lower level of sodium was recorded in WYC-12 (11.22±3.73) and higher level was recorded in WYC-I (85.89±12.51) of summer season. The large amount of sodium in the soil resulted in high pH of the soil samples closest to the industries, since it is well known that high sodium content leads to alkalinity [15], [16]. Sodium content variations among industrial and WYC sites were found to be significant ($p<0.01$). Sodium level in vicinity of industries and WYC was recorded lower in winter and higher in summer. Significant variations ($p<0.01$) were estimated among seasons for WYC soil samples, whereas no significant variations among seasons were observed in industrial soil samples.

In vicinity of industries average mean values of potassium of two seasons varied significantly ($p<0.01$) from 10.67±2.71 mg/L to 165.89±24.69 mg/L at T.P-II of winter and S.M-1 site of summer season respectively (Table 1.1). The average mean value of the three industries for all sites and seasons was observed to be higher at paper mill (88.70 mg/L) followed by sugar mill (77.99 mg/L) and thermal power plant (22.06 mg/L). Potassium correlated significantly with Cd, Na, Ni, Mg, Salinity, Mn and EC with r values (0.66, 0.71, 0.79, 0.80, 0.83, 0.85 and 0.86 respectively) depicted in Table (1.3). Potassium content of soil in vicinity of Western Yamuna canal was found to be higher at WYC-1 site (77.89±14.82 mg/L) and lower at WYC-7 (7.22±1.28 mg/L) site in summer and winter season respectively (Table 1.2). The potassium level showed the downward trend away from the industrial area in Western Yamuna Canal. The differences were estimated to be significant among sites ($p<0.01$). Significant positive correlation of Potassium was observed with all studied parameters except with pH as shown in Table (1.4). Potassium content in soil was found to be higher in summer compared to winter season in vicinity of industries and WYC soil samples. The variations of potassium content in soil were found to be significant between seasons in vicinity of industries and WYC ($p<0.01$). The major source of potassium in natural water is weathering of the rocks but the quantities increase in the soil due to disposal of waste water from surrounding area.

Large amounts of calcium and magnesium influence soil acidity and are known to alter ionic balance in soil [17]. Calcium ranged from 94.89±16.56 to 526.67±29.79 mg/kg at T.P-II and S.M-II site respectively in vicinity of industries and was found to vary significantly ($p<0.01$) among industries. (Table 1.1). By comparing all the three industries higher average mean value of calcium of soil was found in sugar mill, followed by paper mill and thermal power plant. Significant correlation of Calcium was observed only with Mn ($r = 0.78$), Ni ($r = 0.80$), Mg and Na ($r = 0.84$) (Table 1.3). Along WYC the values of calcium were conspicuously high at the sites nearer to the industries and gradually decreased with increasing distance significantly ($p<0.05$). Correlation of Calcium with almost all studied parameters was also found to be positively significant (Table 1.4). Calcium content was found to be higher in summer season compared to winter season in vicinity of industries and WYC. A two way analysis of variance showed a significant variation among seasons in WYC soil samples.

In the present study magnesium content in vicinity of industries varied significantly ($p<0.01$) from 53.67±7.04 mg/kg to 117.33±19.23 mg/kg at T.P-II and S.M-I site respectively (Table 1.1). Higher average mean value of magnesium was found to be at sugar mill (104.74 mg/kg) followed by paper mill (96.22 mg/kg) and thermal power plant (68.15 mg/kg). Significant positive correlation of Magnesium was observed with Cd ($r = 0.67$), Na ($r = 0.77$), K ($r = 0.80$), Ni ($r = 0.82$), Ca ($r = 0.84$) and Mn ($r = 0.89$) (Table 1.3). In vicinity of WYC magnesium in soil samples varied from 16.26±0.21 to 68.64±15.55 mg/kg at WYC-20 and WYC-2 site respectively (Table 1.2). The variations in magnesium content among different industries were found to be significant ($p<0.01$). A decreasing order of trend of magnesium content from WYC-1 to WYC-20 site was observed; this indicates a definite influence of industrial and domestic waste on soil nearer to the city. A highly significant positive correlation of Magnesium was observed with almost all studied parameters (Table 1.4).

Cadmium is highly toxic metal, not known to have any beneficial effects for plants and animals. Many cadmium compounds are also believed to the carcinogenic [18]. Some sources of phosphate in fertilizers contain Cadmium in amounts up to 100% mg/kg [19] which can lead to an increase in the concentration of Cadmium in soil [20]. Cadmium content in soil in vicinity of industries ranged from 0.04 to 1.80 mg/kg. Higher values of cadmium were found at S.M-I site. Among the three industries, average mean value of cadmium across all sites and seasons was found to be higher at sugar mill sites (0.65 mg/kg) followed by paper mill (0.46 mg/kg) and thermal power plant (0.13 mg/kg) as shown in Fig 1.4. Cadmium concentration was found to be higher in summer season compared to winter season. Significant positive correlation of Cd was observed with EC and K (r = 0.66), Mg (r = 0.67), Ni (r = 0.82) and Mn (r=0.90) (Table 1.3)

In soil samples chromium levels around the industries ranged from 1.50 (T.P-III) to 51.5 (P.M-II) mg/kg and were considerably higher in the sample collected from vicinity of paper mill followed by sugar mill and thermal power plant. Approximately 14% of soil samples had chromium concentration above the desirable limit (35 mg/kg) of WHO. Average mean value of chromium of both seasons showed higher concentration of chromium in summer season compared to winter season. Chromium exhibited significant positive correlation only with EC (r = 0.68) from all studied parameters in soil samples (Table 1.3).

Copper is retained in soils through exchange and specific adsorption mechanisms. The copper content in the industrial area soils during summer season ranged from 1.25 mg/kg to 50 mg/kg and varied up to 2.00 mg/kg to 50 mg/kg in winter season (Fig. 1.4). Higher concentration of copper was found to be in paper mill sites followed by sugar mill sites and thermal power plant. In summer copper concentration was found to be higher compared to winter season. Copper of soil samples exhibited significant positive correlation only with EC and Na (r = 0.68), however, a negative correlation was observed with pH (r = - 0.23) (Table 1.3).

Manganese concentration in soil samples varied from 6.0 to 94 mg/kg at T.P-III and S.M-I site respectively. Higher concentration of manganese was found to be at sugar mill site followed by paper mill and thermal power plant (Fig 1.4). Manganese concentration was found to be much higher in winter season compared to summer season. Significant positive correlation of Mn with almost all studied parameters was observed (Table 1.3).

Table 1.1 Mean concentrations of physiochemical parameters of industrial soil samples

Parameters	Seasons	Sugar mill			Paper mill			Thermal power plant		
		S.M I	S.M II	S.M III	P.M I	P.M II	P.M III	T.P I	T.P II	T.P III
pH	Summer	7.51±0.47	7.44±0.32	8.03±0.83	8.17±0.72	7.39±0.42	7.58±0.42	7.78±0.68	7.60±0.45	7.88±0.68
	Winter	7.59±0.17	7.88±0.44	7.91±0.54	7.93±0.46	8.02±0.85	8.16±0.61	7.72±0.32	7.97±0.57	8.09±0.52
EC	Summer	1.58±0.31	0.64±0.09	1.39±0.65	1.51±0.75	1.55±0.58	1.77±0.31	0.22±0.06	0.39±0.14	0.28±0.09
	Winter	2.88±0.68	0.99±0.35	1.38±0.63	1.09±0.47	2.06±0.67	2.25±0.78	0.35±0.12	0.36±0.08	0.42±0.14
SAL	Summer	0.87±0.14	0.30±0.06	0.82±0.35	0.61±0.46	1.29±0.38	1.50±0.32	0.00	0.03±0.03	0.00
	Winter	1.40±0.46	0.44±0.24	0.68±0.31	0.18±0.06	1.13±0.24	0.56±0.31	0.03±0.03	0.03±0.03	0.10±0.10
Na	Summer	49.22±7.95	54.33±5.17	53.78±8.35	52.00±17.31	79.67±22.78	79.44±17.55	41.11±10.58	22.67±5.93	22.56±4.81
	Winter	70.69±7.01	57.29±14.71	75.61±10.65	28.00±4.44	50.56±22.16	69.00±19.10	10.67±1.84	14.78±2.15	17.44±1.74
K	Summer	165.89±24.69	98.11±5.57	56.78±19.57	112.11±13.84	146.56±36.10	92.56±26.97	44.33±5.85	23.89±8.46	24.11±7.16

	Winter	45.67±15.88	33.17±4.97	29.67±4.92	59.93±3.13	34.33±18.01	38.67±7.51	12.33±0.59	10.67±2.71	20.33±3.11
Ca	Summer	430.00±35.90	526.67±29.79	338.22±26.89	280.89±19.17	253.11±8.00	356.33±23.70	150.22±9.69	94.89±16.56	122.67±13.92
	Winter	267.56±29.68	313.78±28.24	298.67±64.70	201.78±25.59	236.44±22.61	325.33±53.17	134.89±17.99	167.78±31.59	147.56±3.11
Mg	Summer	117.33±19.23	112.67±7.78	99.56±1.18	104.00±2.31	99.33±6.57	93.33±8.06	87.11±9.28	53.67±7.04	65.56±12.37
	Winter	102.89±3.27	107.78±18.23	88.22±4.56	90.00±4.44	94.67±6.74	96.00±4.02	86.67±4.81	56.56±11.11	59.33±11.44

A lot of nickel released into the environment ends up in soil or sediment where it strongly attaches to particles containing iron or manganese. Under acidic conditions, nickel is more mobile in soil and might seep into groundwater [21]. In the present investigation nickel concentration ranged from 2.3 mg/kg (T.P-III) to 25 mg/kg (P.M-II). Maximum nickel content was found to be at paper mill samples followed by sugar mill samples and thermal power plant. In summer season higher values of nickel was found in soil samples compared to winter season. Nickel exhibited a positive correlation with almost all studied parameters, however, significant positive correlation was observed with EC (r = 0.75), Salinity (r = 0.74), K (r = 0.79), Ca (r = 0.80), Cd and Mg (r = 0.82), Na (r = 0.84) and Mn (r = 0.89) as depicted in Table (1.3).

CONCLUSION:

In case of soil samples in vicinity of industries and WYC it was found that the soil was affected due to pollution, since the pH in vicinity of industries and WYC was observed to be alkaline. The concentration of EC, salinity and potassium were found to be higher in vicinity of paper mill soil samples followed by sugar mill and thermal power plant. However, concentration of sodium, calcium and magnesium were higher in sugar mill vicinity soil samples followed by paper mill and thermal power plant. Higher concentrations of heavy metals (Cr, Ni, Cu) were generally present in paper mill vicinity soil samples, probably due to toxic dyes, bleaching agents, salts, acids and alkalis in paper mill. Chromium and nickel were found in abundance in paper mill soil samples followed by sugar mill and thermal power plant soil samples. Approximately 14% of soil samples had chromium concentration above the desirable limit of WHO. The values of cadmium and manganese were found to be higher in sugar mill vicinity soil samples followed by paper mill and thermal power plant soil samples. Along WYC soil samples, the concentration of all selected parameters were found to decrease with increasing in distance from the industrial area, this indicates a definite influence of industrial and domestic waste on soil nearer to city. The results obtained definitely indicate that effluents and other waste materials from the paper mill and sugar mill have contributed to some significant alteration of soil quality in the vicinity of the mills and the natural soil composition has been affected similar to surface and ground water quality.

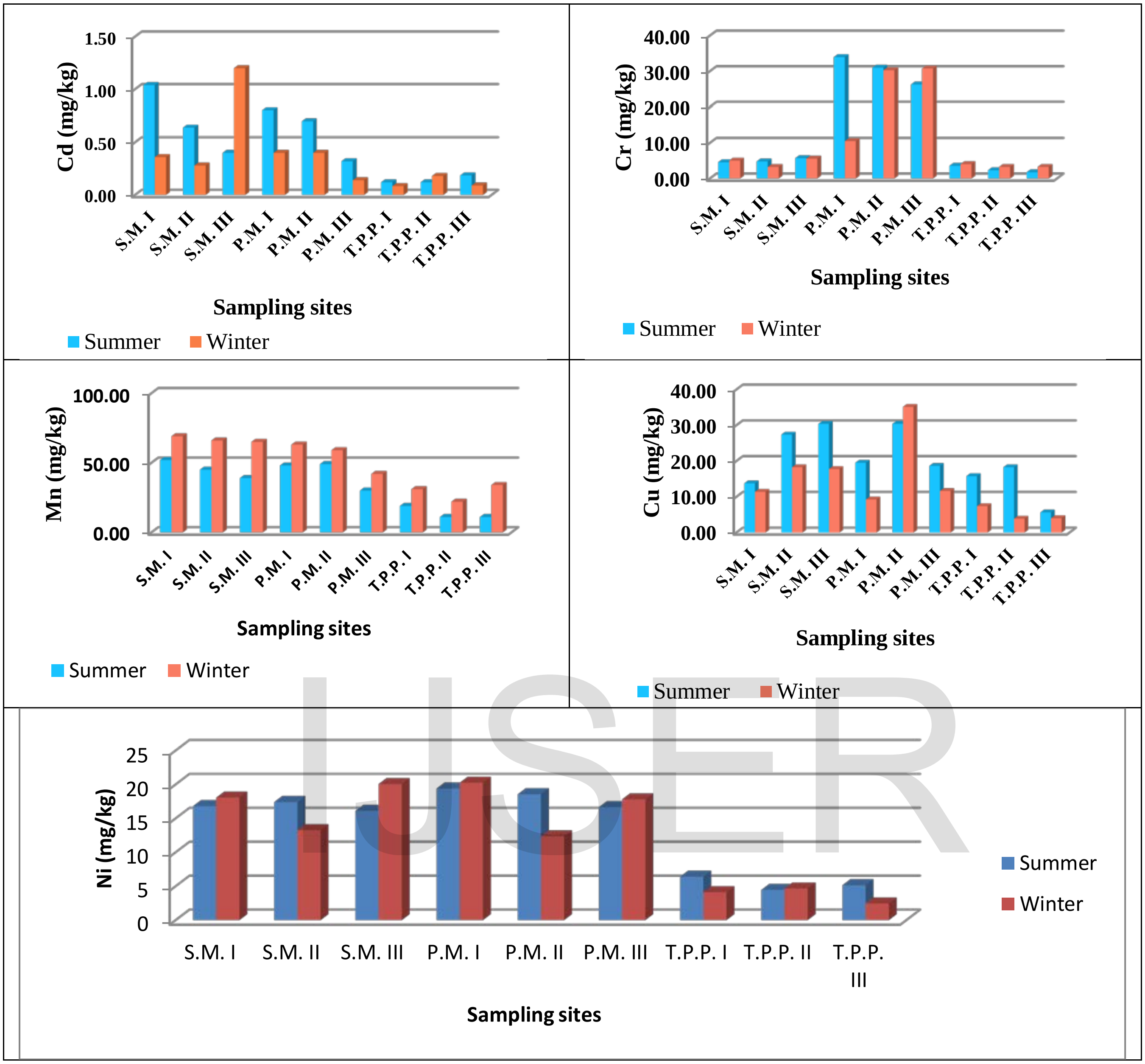

Fig 1.4 Heavy metal concentration in soil samples of industrial vicinity area

Table 1.2 Mean concentrations of physiochemical parameters of soil samples along Western Yamuna Canal

Site	Season	pH	EC	SAL	Na	K	Ca	Mg
WYC-I	Summer	7.70±0.19	2.88±0.73	1.08±0.48	85.89±12.51	77.89±14.82	148.67±8.06	64.89±8.92
	Winter	8.12±0.10	1.78±0.68	0.83±0.36	66.11±11.07	43.00±11.41	107.39±18.17	58.78±11.23
WYC-2	Summer	7.53±0.27	2.52±0.67	0.88±0.32	35.33±14.54	56.44±16.77	152.00±3.36	50.67±4.81
	Winter	7.89±0.18	2.12±0.53	1.17±0.26	36.89±9.62	42.44±6.27	109.93±9.11	68.64±15.55
WYC-3	Summer	7.97±0.04	0.76±0.18	0.20±0.06	16.89±5.90	26.89±7.80	89.00±5.86	38.89±3.89
	Winter	7.96±0.33	1.04±0.11	0.46±0.05	26.33±8.30	18.78±6.34	83.82±13.27	33.98±4.35
WYC-4	Summer	7.85±0.09	0.84±0.09	0.23±0.03	62.00±17.40	25.78±11.17	77.22±8.78	40.22±2.51
	Winter	7.87±0.12	0.70±0.17	0.30±0.21	48.78±10.72	17.22±0.56	53.02±6.87	42.89±6.17
WYC-5	Summer	7.54±0.28	0.70±0.21	0.37±0.27	32.89±10.23	28.22±6.09	82.67±14.05	43.33±6.05
	Winter	7.81±0.13	1.06±0.50	0.50±0.25	23.67±6.01	10.00±2.60	60.24±15.20	31.21±4.45
WYC-6	Summer	7.95±0.01	0.61±0.25	0.10±0.06	16.89±5.02	22.33±5.19	92.44±7.28	28.67±3.06
	Winter	8.04±0.29	0.39±0.16	0.08±0.08	20.33±6.03	7.56±1.18	42.30±6.97	26.33±1.64
WYC-7	Summer	7.74±0.32	0.67±0.09	0.16±0.03	29.44±10.31	35.78±9.88	69.33±4.81	33.33±1.68
	Winter	7.98±0.35	0.29±0.07	0.00	16.89±5.21	7.22±1.28	55.44±3.93	25.91±3.92
WYC-8	Summer	7.50±0.32	0.69±0.18	0.16±0.09	17.00±6.11	29.56±12.63	61.33±8.15	36.67±7.81
	Winter	7.84±0.21	0.43±0.05	0.03±0.03	21.56±8.23	9.44±2.16	47.11±7.12	27.92±0.75
WYC-9	Summer	7.82±0.14	0.64±0.17	0.16±0.08	16.56±4.30	22.67±6.70	64.00±3.01	35.11±1.94
	Winter	7.94±0.17	0.40±0.10	0.07±0.07	25.22±11.72	23.89±6.23	44.08±3.08	28.89±4.12
WYC-10	Summer	7.46±0.36	0.57±0.18	0.13±0.09	22.00±7.56	16.33±4.41	67.22±5.68	25.56±0.59
	Winter	8.04±0.23	0.37±0.07	0.04±0.04	24.67±13.32	17.00±3.84	52.68±4.38	24.10±3.76
WYC-11	Summer	7.47±0.23	0.48±0.12	0.07±0.03	17.89±4.20	27.56±11.39	52.67±3.71	30.44±2.62
	Winter	7.97±0.32	0.32±0.14	0.07±0.07	17.44±4.27	12.67±4.86	49.29±6.40	31.61±6.44
WYC-12	Summer	7.37±0.39	0.69±0.10	0.17±0.07	11.22±3.73	19.67±9.52	56.00±6.54	29.22±2.80
	Winter	7.95±0.34	0.37±0.14	0.03±0.03	16.67±3.93	15.33±5.12	51.03±7.81	26.88±4.29
WYC-13	Summer	7.51±0.40	0.80±0.10	0.23±0.07	17.89±3.66	19.44±6.54	54.11±3.82	23.78±3.13
	Winter	8.13±0.43	0.63±0.35	0.19±0.19	20.89±5.61	12.44±3.02	54.48±4.43	21.48±7.69
WYC-14	Summer	7.59±0.33	0.61±0.12	0.13±0.09	19.56±2.74	25.89±4.89	59.78±3.80	24.67±0.67
	Winter	8.11±0.19	0.35±0.09	0.03±0.03	19.78±7.79	16.00±7.27	53.92±2.41	21.92±3.71
WYC-15	Summer	7.52±0.34	0.56±0.21	0.13±0.09	17.67±3.50	22.11±8.11	55.11±5.50	21.67±2.87
	Winter	7.87±0.24	0.31±0.11	0.03±0.03	21.89±8.44	18.67±6.16	49.56±4.70	20.37±4.48
WYC-16	Summer	7.75±0.06	0.54±0.19	0.13±0.09	20.00±2.80	13.22±5.06	60.00±2.14	24.67±3.91
	Winter	7.80±0.30	0.27±0.07	0.00	26.33±7.02	11.89±3.55	50.21±4.95	26.92±1.52
WYC-17	Summer	8.00±0.04	0.49±0.16	0.10±0.06	23.00±1.58	16.11±4.78	52.44±3.49	25.89±6.01
	Winter	7.80±0.18	0.36±0.08	0.00	19.00±2.03	15.67±4.51	45.29±4.86	21.82±5.14
WYC-18	Summer	7.73±0.09	0.48±0.14	0.10±0.06	21.56±2.32	14.56±3.30	47.11±1.24	24.78±2.80
	Winter	7.85±0.18	0.30±0.10	0.00	21.33±2.91	13.22±3.31	47.22±4.77	18.53±3.22
WYC-19	Summer	7.65±0.16	0.48±0.12	0.10±0.06	22.44±4.15	12.22±1.46	48.78±1.97	19.34±4.06
	Winter	7.94±0.23	0.30±0.10	0.00	23.44±5.64	12.89±3.08	40.36±2.96	17.97±2.71
WYC-20	Summer	7.63±0.08	0.43±0.16	0.10±0.06	17.22±2.80	10.00±2.03	47.22±7.09	20.00±1.20
	Winter	7.87±0.24	0.27±0.07	0.00	16.67±4.04	11.56±3.72	42.22±4.96	16.26±0.21

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Table 1.3 Correlation matrix among physiochemical parameters and heavy metals concentration of industrial vicinity soil samples (significant level 0.05)

	pH	EC	SAL	Na	K	Ca	Mg	Cd	Cr	Cu	Mn	Ni
pH	1											
EC	-0.29	1										
SAL	-0.33	0.98	1									
Na	-0.23	0.86	0.90	1								
K	-0.42	0.86	0.83	0.71	1							
Ca	-0.33	0.56	0.62	0.84	0.63	1						
Mg	-0.40	0.64	0.64	0.77	0.80	0.84	1					
Cd	-0.06	0.66	0.63	0.63	0.66	0.62	0.67	1				
Cr	0.17	0.68	0.62	0.56	0.56	0.19	0.31	0.16	1			
Cu	-0.23	0.68	0.60	0.68	0.49	0.49	0.54	0.58	0.49	1		
Mn	-0.23	0.73	0.68	0.72	0.85	0.78	0.89	0.90	0.32	0.62	1	
Ni	0.00	0.75	0.74	0.84	0.79	0.80	0.82	0.82	0.54	0.56	0.89	1

Table 1.4 Correlation matrix among physiochemical parameters of soil samples along Western Yamuna Canal (significant level 0.05)

	pH	EC	SAL	Na	K	Ca	Mg
pH	1						
EC	0.07	1					
SAL	0.03	0.99	1				
Na	0.25	0.74	0.73	1			
K	0.11	0.95	0.92	0.77	1		
Ca	0.18	0.97	0.97	0.70	0.92	1	
Mg	0.09	0.93	0.93	0.78	0.91	0.93	1

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