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Assessment of Heavy Metals Contamination of Agricultural Field around Brick Kilns in Joypurhat District, Bangladesh

Tamjid-Us-Sakib[1], Mst. Shanjida Sultana[2]
[1,2]Institute of Mining, Mineralogy and Metallurgy (IMMM), Bangladesh Council of Scientific and Industrial Research (BCSIR), Joypurhat-5900, Bangladesh
([1]abir.swe@gmail.com, [2]shammiswe@yahoo.com)

***Abstract*-**The present work assessed the heavy metal contamination of agricultural field around two selected brick kilns, where brick kiln is in the center of agricultural land using two soil pollution indices such as geo accumulation index (Igeo) and single element pollution index (SEPI). For conducting this experiment, a total of 10 soil samples and 13 plant samples were collected from the soil surface which was almost 50-200 m away from the kilns. During the study, soil properties such as pH, EC, organic carbon content and organic matter was also determined. The heavy metal (Pb, Cr, Ni, Zn and Cu) concentrations were determined using Atomic Absorption Spectrophotometer. Concentrations of Pb, Cr, Ni, Zn and Cu were found to be below detection limit to 7.75, 10.0 to 64.94, 4.62 to 16.39, 0.20 to 3.37 and 2.69 to 9.63 ppm respectively. The results of single element pollution index (SEPI) and geo-accumulation index (Igeo) of soils of studied area indicated that the soils are unpolluted with regards to Pb, Cr, Ni, Zn and Cu. Interestingly, it was found that there is a prominent difference in concentration between plant tissues and soils of investigated area. Plant tissue concentration of Pb, Cr, Ni, Zn and Cu were found to be 6.0 to 62, 19.1 to 113.8, 21 to 75.6, 16.59 to 78.55 and 1.0 to 71.7 ppm respectively. Environmental condition, plants species and soil properties are some factors might be responsible for such differences.

Keywords- *Brick Kilns Emission, Heavy Metals, Soil Contamination, Single Element Pollution Index, Geo Accumulation Index, Plants Tissues*

I. INTRODUCTION

In Bangladesh, the brick kiln industry is one of the fastest-growing sectors which currently manufacturing capacity of 12 billion bricks a year from 4,500 brick kilns surrounding all major cities of Dhaka, Khulna, Rajshahi, and Chittagong, and expected to grow 50 % by 2020 [1]. Bangladesh has about 6,000 authorized brickfields and numerous illegal ones [2]. According to the Environment Conservation Act 1995 (ECA) and Environment Conservation Rules, 1997, brick industry is Orange B category industry, which is not environment-friendly [3].

In manufacturing seasons of brick, pollution goes to the peak in and around the brick kilns situated area depending on the monsoonal rains. Due to poor technology and the improper burning of coal and wood produces a lot of pollutants during the brick production, among them CO_2, CO, SO_2 and other greenhouse gases are the most common ones [4]. Heavy metals, such as, Pb, Hg, Zn, Cu, Ni, Cr, Fe, Cd and As are also found as a byproducts [5]. Heavy metal and fly ash both fall down to soil due to gravity after emission and they ultimately fall down to the soil and may be taken up by standing plants. Numerous scientists noted that a significant amount of toxic elements are being produced from brick kilns in every year [6][7][8]. A large portion of these is heavy metals are responsible for soil degradation. These metals are equally harmful for both living and non-living environment, which can cause adverse effects on human health and agri-environment [9].

Around Joypurhat district where brick kilns have been increased with the increasing development of urbanization. But a few years ago, the main business of that locality was agricultural practices. As environmental impacts of brick kilns are not clear in that locality, the number of traditional brick kilns is increasing day by day and people adopt all adverse impacts of brick kilns as their fate. A large amount of toxic elements are produced continuously from brick kilns but a no report is available on heavy metal contamination due to brick production in Joypurhat districts. The objective of the present investigation was to find out the concentration of some heavy metals (Pb, Cr, Ni, Zn and Cu) in agricultural soil as well as plants due to the establishment of brick kiln.

II. MATERIALS AND METHODS

A. *Site slecetion*

The selection of the brick kiln was based on nearness to agricultural lands as the study comprised determination of contamination in agricultural land around a brick kilns. For this purpose, two brick kilns namely Site 1 & Site 2 were selected in Joypurhat Sadar Upazila which were surrounded by cropped area and at the time of sampling the brick kilns were in operation. The map of the sampling location was presented in Figure 1 and 2.

Figure 1. Location of sampling points of Site 1

Figure 2. Location of sampling points of Site 2

B. Collection and preparation of Soil Samples

A total of 10 Soil samples (0–15 cm depth) from agricultural field around two brick kiln were collected. All of the sampling point is almost 50-200 m away from the kilns. Around Site-1, seven soil samples were collected from agricultural land surrounding the kilns. At the time of the sampling, it was found that there were only few fields left for cultivation because most of fields are used for collection of soil for brick making purposes or peoples were unwilling to cultivate their land due to low yield. Therefore, around Site-2, only three soil samples were collected. Soil samples were collected using an augar. The GPS coordinates of the sampling site was recorded with the help of a GPS label of each sites are presented in Table I.

TABLE I. SAMPLING LOCATION AND THEIR CORRESPONDING GEOGRAPHICAL POSITIONS

Sampling location	Latitude	Longitude
S-1	25° 4'49.9"N	88°59'56.98"E
S-2	25° 4'50.53"N	88°59'54.57"E
S-3	25° 4'50.35"N	88°59'52.32"E
S-4	25° 4'48.55"N	88°59'51.03"E
S-5	25° 4'46.05"N	88°59'51.01"E
S-6	25° 4'44.45"N	88°59'54.20"E
S-7	25° 4'45.67"N	88°59'57.80"E
S-8	25° 4'49.43"N	89° 0'19.25"E
S-9	25° 4'46.52"N	89° 0'21.77"E
S-10	25° 4'45.89"N	89° 0'15.60"E

Soil samples were collected using an augar. The GPS coordinates of the sampling site was recorded with the help of a GPS and the coordinate values and label of each sites are presented in Table I. The soil samples were collected as outlined by FAO [10] and Jackson [11].

Each of the collected soil samples were dried in the air for 3 days by spreading on separate sheet of thick coarse brown paper. Visible roots and debris were removed from the soil sample and discarded. After air drying, a portion of the sample was broken by gently crashing them by a wooden hammer. The ground soils were passed through a 0.5 mm stainless steel sieve. Soil samples were preserved in plastic containers and labeled properly showing the site number, location and date of collection. The sieved soils were used for chemical and physico-chemical analysis.

C. Collection and preparation of Plant Samples

A total of 13 different types of plant species from agricultural field around two brick kiln were collected. Around Site-1, ten different types of plant species were collected from seven sampling points within agricultural land surrounding the kilns. At the time of the sampling, it was found that all the plants species was in their maturity stage. It was also found that plants species were not available at all direction due to operational activities of brick kilns. Therefore, only one plant species was found around Site-2. All the plant species were collected manually through uprooting them. Different plants species from different sampling locations with their code were presented in table II.

All samples were put in polythene zip-bags and transported to the laboratory on the day of sampling. All the plants species were washed in fresh running water to eliminate dusts, dirties, possible parasites or their eggs and were finally washed with deionized water. The clean vegetable samples were air-dried and placed in an electric oven at 70-80°C for 72–96 hours depending on the sample size. The dry vegetable samples were homogenized by grinding using a ceramic coated grinder and used for metal analysis.

TABLE II. DIFFERENT PLANTS SPECIES FROM DIFFERENT SAMPLING LOCATIONS WITH THEIR CODE

Sampling location	Plants species	Code
S-1	Jackfruit fruits	JF
S-2	Paddy root	PR
	Paddy stem	PS
S-3	Wheat root	WR
	Wheat stem	WS
	Wheat fruit	WF
S-4	Banana leaf-1	BL-1
S-5	Banana leaf-2	BL-2
S-6	Banana leaf-3	BL-3
S-7	Brinjal leaf	BRL
	Chinese spinash stem	CSS
	Chinese spinash leaf	CSL
S-8	No plants species was found	-
S-9	No plants species was found	-
S-10	Coriander whole plants	CWP

D. Determination of physic-chemical Properties of Soil

Among physic-chemical properties of soil, pH, EC, texture and organic carbon of the soil samples were analyzed. Soil pH was measured in a soil water suspension in the 1:2.5 soil:water ratio (w:v), by a glass electrode pH meter. The electrical conductivity of the soil was measured in the saturation extract of the soil with the help of an EC meter. The total organic carbon of the soil samples was determined by wet oxidation method by Walkley and Black [12]. Organic matter was calculated by multiplying the percent value of organic carbon by conventional Van Bemmelen's factor of 1.724.

E. Determination of heavy metals content of Soil and Plants

Total copper (Cu), lead (Pb), chromium (Cr), nickel (Ni) and zinc (Zn) content of the soil and plant samples were determined directly by using Atomic Absorption Spectrophotometer (Varian AA240) from nitric acid (HNO_3) digestion.

III. RESULTS AND DISCUSSION

A. Physic-chemical properties of Soil

Results of physico-chemical properties e.g., pH, EC, Organic carbon and organic matter of soil are presented in table III. Soil pH is an important index of ecological condition of terrestrial environment [13]. It affects the availability of nutrients to plants and the activity of soil microorganisms. The pH values of the collected soil samples of agricultural field around the brick kilns ranged from 3.7 to 6.5. The lowest and highest pH values for soils were analyzed 3.7 and 6.5 at S-4 and S-1 respectively where site 4 is paddy field near the brick kilns. Results showed that the soil samples ranged from extremely acidic to slightly acidic in most cases.

TABLE III. PHYSICO-CHEMICAL PROPERTIES OF SOIL

Location	pH	EC µS/cm	Organic carbon (%)	Organic matter (%)
S-1	6.5	375	0.15	0.26
S-2	6.1	66.1	0.39	0.67
S-3	5.65	39.9	0.30	0.52
S-4	3.7	46.1	0.48	0.83
S-5	4.3	83.3	0.39	0.68
S-6	5.7	109.2	0.53	0.91
S-7	5.3	66.0	0.36	0.62
S-8	5.7	102.1	0.35	0.60
S-9	4.7	77.1	0.42	0.729
S-10	4.9	531.5	0.51	0.89

Agricultural soil electrical conductivity is an indirect measurement that correlates with several soils physical and chemical properties. The electrical conductivity (EC) of soil-water mixtures indicates the amount of salts present in the soil [14]. The values EC of the collected soil samples of agricultural field were ranged from 39.9 to 531.5 µS/cm. The lowest and highest EC values for soils were recorded 39.9 and 531.5 at S-3 and S-10 respectively (Figure 4) where site 3 is wheat field near the brick kilns.

Organic carbon is important parameter of soil that determines beneficial effects on soil quality. Organic carbon of the soil in this study area ranged from 0.15% to 0.53%. The lowest concentration of organic carbon was recorded as 0.15% at the S-1 which was just 75 m away from brick kiln and the highest was 0.53% at S-6 which was about 200 m away from brick kiln. This indicates that organic carbon level in soil samples near to brick kiln has been found poor in range. The percentage of organic carbon is interlinked with organic matter content. So, the results of organic matter followed the same pattern as organic carbon. Soil organic matter content of study area ranged from 0.26% to 0.91%. However, the higher concentration was found at S-6 which is used for banana plantation. The organic matter content at S-1 which was just 50 m away from brick kiln was found lowest (0.25%) due to low organic carbon content [15].

B. Heavy metals in soils

The result presented in Figure 3 showed that the concentration of Pb in collected soil of the study area. The maximum concentration of Pb was 7.75 ppm at S-1 which was just 50 m away from the brick kilns-1. After S-1, the concentration of Pb showed decreasing trend and eventually it was only 1.5 ppm at S-7 of Site-1. On the other hand, the concentration of Pb at S-8 near to the Site-2 was found to be below detection limit and highest concentration was 2.25 ppm at S-9 of Site-2. Figure 4 represents the concentration Cr in the soils of study area. Among heavy metals, highest concentration was recorded for Cr. The concentration of Cr of the collected soils ranges from 10 to 64.94 ppm. The lowest amount of Cr was found at S-1. After that, the concentration of Cr was showed an increasing trend but the concentration was stable with changing site. At S-10, highest concentration of Cr was found which was near about only 100 m away from Site-2.

Total concentration of Ni in collected soil of the study area is depicted in Figure 5. It was noted that the lowest concentration of Ni was found at S-1 and S-8 both of that site was just 50 m away from Site-1 and Site-2 respectively. Among other sites, the concentration more or less varied between 11.24 to 16.39 ppm. The result of total concentration of Zn in collected soils was presented in Figure 6. The concentration of Zn was found to be minor in contrast with other metals in soils. The ranges of Zn were varied from 3.37 to 0.2 ppm. Besides S-1 and S-2, all the sites showed very lower concentration of Zn that is below 0.5 ppm. Total concentration of Cu in collected soil of the study area is depicted in Figure 7 which showed the ranges of Cu were varied from 10.38 to 2.69 ppm. It was found that both S-1 and S-8 that were located only 50 m away from Site-1 and Site-2 showed lowest concentration of Cu when compared with other site. The concentration of other sites varied more or less stable amounts of concentration.

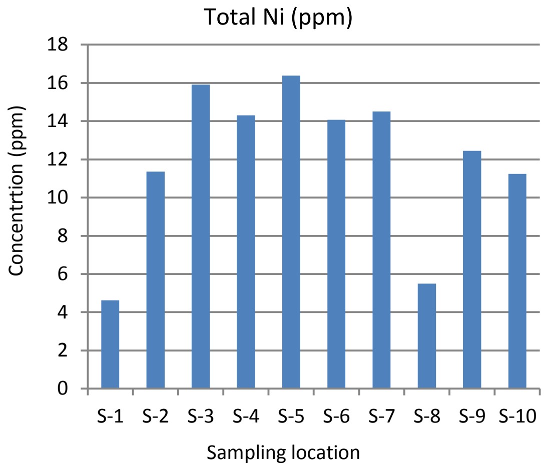

Figure 5. Total Ni contents in soils

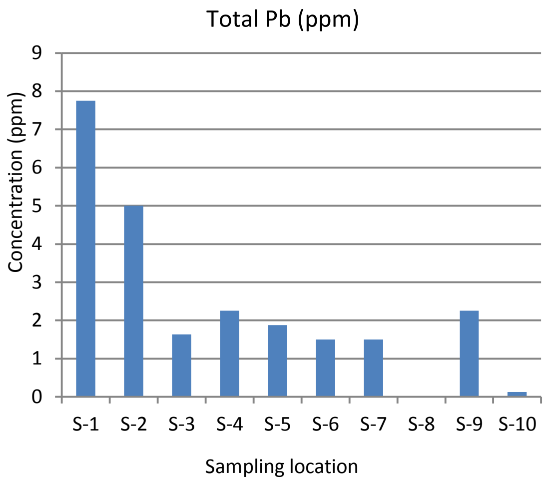

Figure 3. Total Pb contents in soils

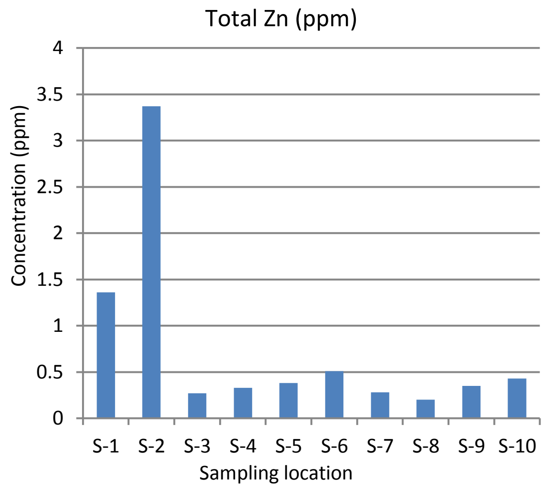

Figure 6. Total Zn contents in soils

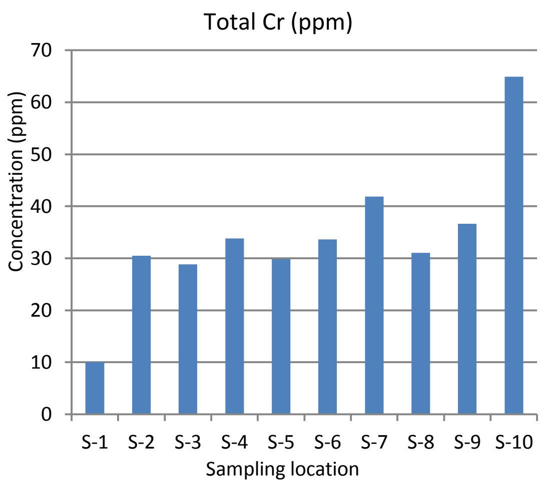

Figure 4. Total Cr contents in soils

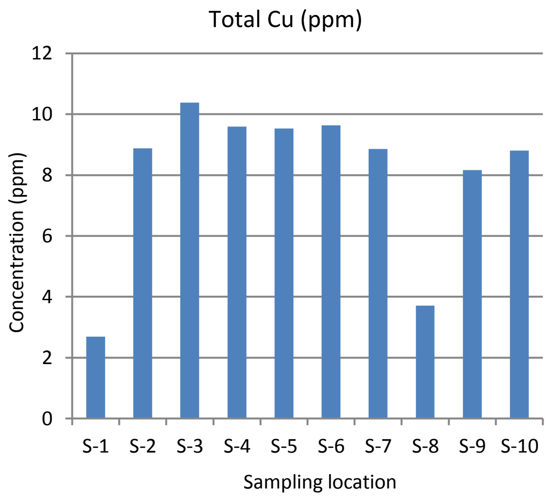

Figure 7. Total Cu contents in soils

The soil pH is generally the most important factor controlling partitioning behavior of heavy metals in soil. Generally, metal sorption to soil is low at low pH (<5.0) and increases as soil pH increases due to the effects of pH on variable-charged sorption sites. Soil pH had significant positive correlation with concentrations of As, Cd, Cr, Cu, Mn, Se, and Zn [16] [17].

Therefore, it was found that site-4, site-5, site-9 and site-10 showed highest amount of heavy metals than others sites because the pH of all these sites were below 5 which may be possible reasons for such variation among different sampling locations. Moreover, when the concentrations of these heavy metals (Pb, Cr, Ni, Zn and Cu) were compared with WHO standards, it was found within the permissible limit for soil [18].

C. Soil Pollution Indices

Soil Pollution Index (SPI) may be used to quantify the degree of pollution of soil. The geo-accumulation Index (Igeo) and Single Element Pollution Index (SEPI) were used to assess the pollution of some metals in agricultural soils around brick kilns.

1) Geo-accumulation Index (Igeo)

Geo-accumulation Index (Igeo) used to assess the presence and intensity of anthropogenic contaminant deposition on surface soil. Geo-accumulation Index (Igeo) was proposed to assess the degree of pollution in aquatic sediments by Müller in 1969, [19] can also be used to the assessment of soil pollution [20]. Igeo is computed by the following equation:

2) Igeo = log2(Cn/1.5Bn)

Where, Cn is the measured concentration of the examined metal (n) in the soil, Bn is the geochemical background concentration of the metal (n), and factor 1.5 is the background matrix correction factor due to lithogenic effects. Igeo was classified into seven grades ranging from unpolluted to extremely polluted (Table IV). In this study, we did not obtain the background values of heavy metals in soils sampling area. Therefore, Igeo has been calculated by using background values according to crustal abundance data of Krauskoph and Bird [21] [22], the reference samples were Zn: 70, Ni: 75, Cr: 100, Pb: 13, and Cu: 55 mg/kg.

TABLE IV. CLASSIFICATION OF CONTAMINATION LEVEL ACCORDING TO IGEO VALUE

Igeo value	Grade	Contamination level
Igeo ≤0	0	Unpolluted
0< Igeo ≤1	1	Slightly polluted
1< Igeo ≤2	2	Moderately polluted
2< Igeo ≤3	3	Moderately severely polluted
3< Igeo ≤4	4	Severely polluted
4< Igeo ≤5	5	Severely extremely polluted
Igeo >5	6	Extremely polluted.

The distribution of heavy metal enrichment based on Igeo in different location has been shown in Table V. The Igeo value of Cr, Cu, Ni, Pb and Zn varied from --1.33 to -9.06 (Table V) which indicates that the negative Igeo values are the results of relatively low levels of contamination. Therefore, based on geo-accumulation index of the studied soil, the investigated area can be considered as unpolluted from all types of metals examined.

TABLE V. GEO-ACCUMULATION INDEX (IGEO) VALUES OF COLLECTED SOIL SAMPLES

Location	Pb	Cr	Ni	Zn	Cu
S-1	-1.33	-3.91	-4.60	-6.27	-4.94
S-2	-1.96	-2.29	-3.31	-4.96	-3.27
S-3	-3.59	-2.38	-2.82	-8.60	-2.99
S-4	-3.12	-2.15	-2.98	-8.33	-3.11
S-5	-3.37	-2.33	-2.78	-8.11	-3.11
S-6	-3.70	-2.15	-2.99	-7.69	-3.10
S-7	-3.70	-1.84	-2.96	-8.56	-3.22
S-8	-3.48	-2.27	-4.36	-9.06	-4.47
S-9	-3.12	-2.03	-3.18	-8.24	-3.34
S-10	-7.29	-1.21	-3.32	-7.92	-3.23

3) Single Element Pollution Index (SEPI)

SEPI is a simple and well known index [23]. Single pollution index in this study was calculated as follows:

4) SEPI= metal content in soils/ permissible level of metal

The permissible level of metals in soil suggested by Kabata-Pendias [24] was used for calculation and each heavy metal was classified as low contamination (SEPI ≤ 1), moderate contamination (1 < SEPI ≤ 3) or high contamination (SEPI > 3) [25]. The SEPI value of Cr, Cu, Ni, Pb and Zn varied from 0.001 to 0.65 (Table VI) which indicated low contamination level. Therefore, results of single element pollution index (SEPI) indicate that all the soil samples of study area can be considered as low contamination level in terms of examined heavy metals.

TABLE VI. SINGLE ELEMENT POLLUTION INDEX (SEPI) VALUES OF COLLECTED SOIL SAMPLES

Location	Pb	Cr	Ni	Zn	Cu
S-1	0.07	0.10	0.07	0.005	0.02
S-2	0.05	0.30	0.19	0.01	0.06
S-3	0.01	0.29	0.27	0.0009	0.07
S-4	0.02	0.34	0.24	0.001	0.06
S-5	0.01	0.30	0.27	0.0013	0.06
S-6	0.01	0.37	0.23	0.0017	0.07
S-7	0.01	0.42	0.24	0.0009	0.06
S-8	0.018	0.31	0.09	0.0007	0.03
S-9	0.02	0.37	0.21	0.001	0.06
S-10	0.001	0.65	0.19	0.001	0.06

D. Heavy metals accumulation in plant species of the study area:

The result obtained from the study showed that heavy metals concentration varied among the selected species and plants parts. The concentration of heavy metals in the plants showed variation with location of each sampling point. Difference in the metals concentration found in the plants species of the current study could be due to various factors e.g. the growing environment (pH, temperature, soil aeration), the types of plants, size and root system the availability of elements to plant in the soil solution or foliar deposits, leaves morphology, soil moisture contents [26].

The result presented in Figure 8 showed that the total concentration of Pb in plants samples of soil of the study area. The concentration of Pb in plants of study area ranged from 6-62 ppm. The maximum concentration of Pb was 62 ppm in PR (Paddy roots) and CWP (Coriander whole plant) at S-2 and S-10 respectively. However concentration of Pb in soil was low as compare to their concentration in plant during the study. It is also noted that root and fruits parts accumulate more metals than others parts of the plants.

Figure 9 represents the concentration Cr in the plants of study area. Among all studied heavy metals, highest concentration was recorded for Cr. The concentration of Cr in the plants ranges from 19.1 to 113.8 ppm. The lowest amount of Cr was found at S-2 in PS (Paddy shoots). The highest amount of Cr was found at S-10 in CWP. Here also root and fruits parts accumulate more metals than others parts of the plants.

Total concentration of Ni in the plants of the study area is depicted in Figure 10. It was noted that the lowest and highest concentration of Ni was found in CSS (China spinach shoots) at S-7 and in PS at S-2 respectively. Both of that sampling point was situated in Site-1. The result of total concentration of Zn in plants of investigated area was presented in Figure 11. The ranges of Zn were varied from 21 to 78.55 ppm. However, concentration of Zn in soil was minor at time of study. Cu concentration in the plants of investigated area is presented in Figure 12. Cu content in plants varied from 1 to 7.1 ppm. Highest concentration of Cu is found in WS (Wheat shoots). Moreover, leaves parts of all species showed comparatively lower concentration of Cu than other plant parts.

Therefore, the concentration of all above mentioned metals was found above the permissible limits of WHO (1996) [27] for plants. The higher concentration of heavy metals in studied plants might be due to the aerial deposition of ash and dust particles produced during the combustion of various fuels [28]. Plants takes different metals through roots and also through stomatal opening, these toxic metals get dissolved in the cell sap and circulate through entire plant [29]. Interestingly, it is observed that there is a marked difference in concentration between plant tissues and soils of investigated area. One of the principle factors that influencing the bioavailability of heavy metals in plants are reported to be soil pH.

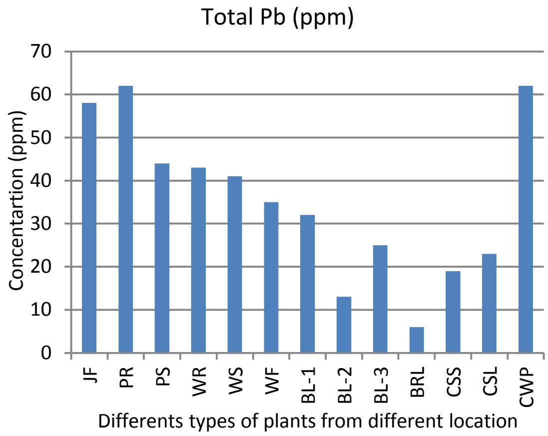

Figure 8. Pb contents in plant species

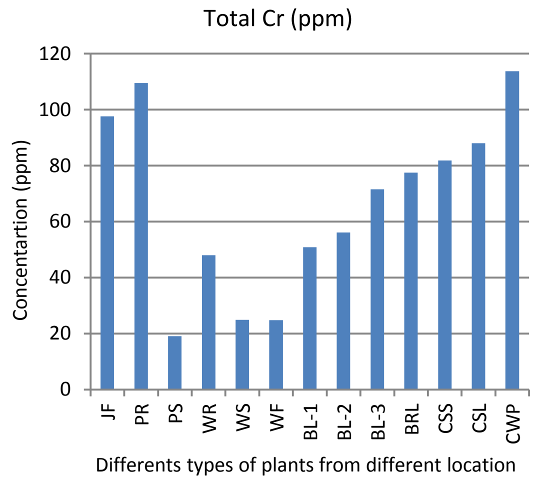

Figure 9. Cr contents in plant species

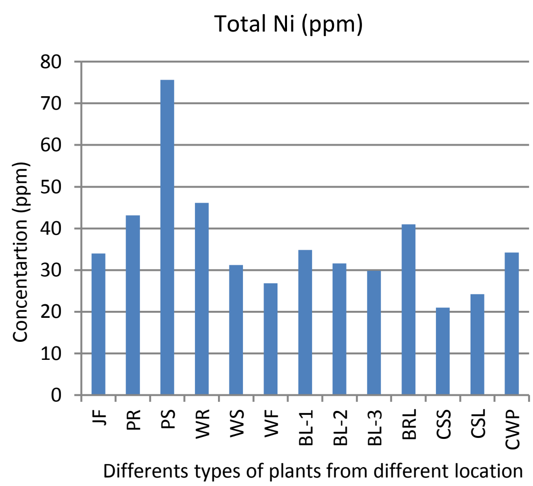

Figure 10. Ni contents in plant species

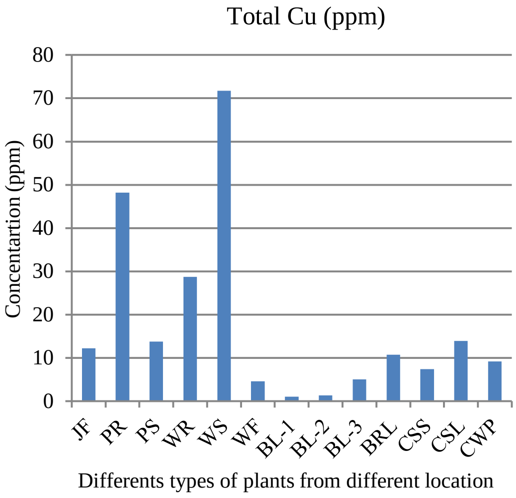

Figure 11. Zn contents in plant species

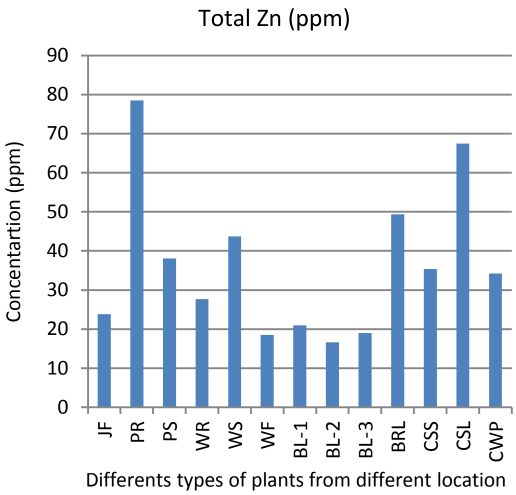

Figure 12. Cu contents in plant species

In our study it was observed that the pH of all soil samples was ranged from extremely acidic to slightly acidic. As is true for all cationic metals, adsorption increased with pH. The retention of the metals did not significantly increase until the pH was greater than 7. Thus, all the cationic metals are present in soil solution at such low pH [30] which ultimately favors all the plants species to uptake these cationic metals and accumulate them in their tissues. Other possible reasons of heavy metals contamination in plants may be by the application of fertilizer and pesticides in agriculture soil [31].

IV. Conclusion

The present study carried out to understand levels of metal contamination in soils and plants of agricultural land around brick kilns. The results indicate that the soil samples studied can be considered to be low levels of contamination. Based on the single element pollution index, the studied area is not contaminated with respect to Pb, Cr, Ni, Zn and Cu and according to study based on geo-accumulation index the area is also unpolluted with regards to Pb, Cr, Ni, Zn and Cu. Among all heavy metals that examined, very low level of concentration was observed for Zn. However, Cr and Ni showed highest level of contamination in compared to other metals. When comparing the contamination among different site, Cr concentration in all the sites of brick kilns-2 showed greater contamination than brick kilns-1. Interestingly, it was found that there is a marked difference in concentration between plant tissues and soils of investigated area. Environmental condition, plants species and soil properties are some factors might be responsible for such differences. The concentration of heavy metals in all investigated plants samples was found nearly above the permissible limits of WHO (1996) for plants.

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