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# Evaluating Heavy Metal Pollution in Soil Near Brick Kilns: Seasonal Trends and Pollution Indices in Haryana, India

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## ABSTRACT

Heavy metal contamination in soil causes negative impact on human life through direct contact, food chain contamination and water pollution. The research on the impact of brick kilns on soil contamination with heavy metal adjacent to the brick kiln located in the village Chuli- Bagdiyaan, of district Hisar, Haryana, was carried out. Certain pollution indicators were determined to measure the heavy metal concentration level in soil. We collected soil samples near brick kilns before and after the monsoon season. The average heavy metals content in each sampling area was greater in the after-monsoon season relative to the before-monsoon and the mean of heavy metal concentrations was present in the sequence prescribed as: Cd<Pb<Cr<Zn<Cu<Fe in the after-monsoon season and Cd<Cr<Pb<Zn<Cu<Fe in the before-monsoon season. Pollution indicators value shows the gradual degradation of soil due to metal contamination near brick kilns.

**Keywords**: Heavy metal Contamination, Brick kilns, Pollution indices, Soil deterioration, Soil pollution, Soil quality.

## INTRODUCTION

Soil is a vital natural resource for all living things on earth. All animal and human beings depend on soil for their day-to-day needs. Soil acts as a dynamic link between the lithosphere and the biosphere. For the development of a country industrialization is the key factor, but it enhances the environmental pollution[1]. In developing countries, from brick kiln's emission soil pollution and air pollution are common which directly affect the surrounding environment. The brick kiln's emissions are not only cause of air pollution but degraded the top soil quality of surrounding area and decreased the agricultural production by reducing the organic matter and nutrient in the soil[2,3]. As a potential source of soil pollution brick kilns cause heavy metal contamination and reduce nutrients in the soil and plants of surrounding area[4]. Gaseous pollutants and ash emitted from brick kilns, reduces the top soil macronutrients and micronutrients, and directly affect the human health and plant growth[5,6]. Brick kiln emissions degraded the soil quality by diminishing the soil's nutrients and organic material and increasing the level of trace metals content in the soil, deteriorating the soil quality, which is harmful to both human well-being and the nearby area's environment. The soil surrounding the brick kiln region may include heavy metals from a variety of sources, including industrial processes, wood burning for fuel and coal combustion, tyre and furnace oil in the brick kiln[7]. Every year, different environmental hazardous elements, like heavy metals from brick kilns, are released into the atmosphere, which are mixed up with air, causing air pollution and the remaining elements retained in the soil and creating soil toxicity. Therefore, the buildup of hazardous elements in soil is a growing issue because of their potential risks and negative impact on soil ecosystems[8,9]. $C_f$, $I_{geo}$ and PLI etc. are valuable pollution indicators to determine the soil pollution with reference to heavy metals[10]. The core purpose of this research is to identify the consequences of brick kiln's operation on the quality of soil by analyzing the heavy metal content in soil surrounding to brick kiln located in the village of Chuli Bagdiyaan, in the district of Hisar, Haryana. No study was reported in this area earlier. This study suggested the implementation of eco-brick manufacturing technologies to diminish heavy metal emissions from the operations of brick kilns. For good agricultural production and better environmental health, there is a great need to analyze the physicochemical properties of soil from time to time.

## MATERIALS AND METHODS

### Research area

To analyze the heavy metals concentration in soil proximal to brick kilns, the brick kiln was selected near the agricultural area. In order to accomplish this, a brick kiln surrounded by cropped area was selected in the village of Chuli Bagdiyaan, which is situated in the Hisar district. Hisar district is situated in the south-western region of Haryana state, with geographical locations between $28^0$ 59' and $27^0$ 46' north latitude and $75^0$ 11' and $78^0$ 18' east longitude and have about 200 active brick kilns.

### Collection of samples of soil

The samples of soil were collected in April and November, 2023 on the basis of periodic variations, which were the periods of before the monsoon season (April-May) and after the monsoon season (October-November). During the months of April (Before-monsoon) and November (After-monsoon) 2023, a total of 144 soil samples in triplicate were collected from depths of 0-15 cm and 15-30 cm at 5-meters, 30-meters, and 50-meters away from the brick kiln on all the sides i.e., north, south, east and west. After collection, each of the samples was transferred into cloth bags and labeled appropriately with a waterproof marker (Table 1). Samples of soil were stored in a cold and dry place at room temperature in a tray for 6 days. After this, using a porcelain mortar and pestle, the soil samples were crumbled and external substances were removed using a stainless sieve. For further analysis the sieved samples were preserved in airtight clean Ziploc bags.

**Table 1: Label of the selected soil samples**

| Distance from Brick kiln(meter) | Depth(in centimeter) | Sampling areas |
|---|---|---|
| 5 m | 0-15 cm | BKC1 |
| 5 m | 15-30 cm | BKC2 |
| 30 m | 0-15 cm | BKC3 |
| 30 m | 15-30 cm | BKC4 |
| 50 m | 0-15 cm | BKC5 |
| 50 m | 15-30 cm | BKC6 |

### Soil analysis

Processing of soil samples was done with a mixture of nitric acid and sulfuric acid and then analyzed for heavy metals, viz. Cu, Pb, Cd, Cr, Fe and Zn, by Atomic Absorption Spectrophotometer (AAS). Three samples of soil from every sampling area were taken and means were calculated for each measured parameter.

### Pollution Indices

### Geo-accumulation Index ($I_{geo}$)

$I_{geo}$ is a valuable tool for assessing the contamination caused by hazardous elements. One of the main goals of evaluating the $I_{geo}$ is the identification of the degree of soil pollution. Geo-accumulation index is described as an elevated metal concentration above baseline level and it was evaluated by applying the literature method[11,12] given as below:

$$I_{geo} = Log_2[C_n/1.5\ B_n] \quad (1)$$

In equation (1): $C_n$ = amount of the

assessed trace metal in the examined sample of soil, $B_n$ = background value of the assessed metal or reference value and factor 1.5 is used to lessen the background discrepancies. The stated world average elemental concentration in milligrams per kilogram is Cu = 45, Mn = 850, Fe = 47200, Cd = 0.30, Ni = 68, Cr = 90, Zn = 95 and Pb = 20[13]. The extent of metal pollution in soil evaluated by using seven classes of contamination. The classes categorized as: very heavily polluted → $I_{geo}$ greater than 5; heavily to very heavily polluted → $I_{geo}$ greater than 4 but less than or equal to 5; heavily polluted → $I_{geo}$ greater than or equal to 3 but less than 4; slightly to heavily polluted → $I_{geo}$ greater than or equal to 2 but less than 3; slightly polluted → $I_{geo}$ greater than or equal to 1 but less than 2; non-polluted to slightly polluted → $I_{geo}$ greater than or equal to 0 but less than 1 and non-polluted → $I_{geo}$ less than 0[14].

**Degree of Contamination ($C_d$) and Contamination Factor ($C_f$)**

In this research to express the contamination caused by toxic metals, equation (2) was applied to describe Contamination Factor ($C_f$) and equation (3) applied for the Degree of Contamination ($C_d$);

$$C_f = C_n/C_o \quad (2)$$

$$C_d = \Sigma\, C_f \quad (3)$$

In equation (2): $C_n$ = assessed metal content in the examined area and $C_o$ = reference concentration or the background value of the assessed metal in uncontaminated soil[15]. The level of contamination may be categorized as:

Minimal contaminated → $C_f$ less than 1;
Slightly contaminated → $C_f$ less than 1 but greater than 3;
Significantly contaminated → $C_f$ less than 3 but greater than 6;
Heavily contaminated → $C_f$ greater than 6.

The addition of all contributing contamination factors describes the overall degree of contamination ($C_d$) and is classified in to four categories as follows:

Less extent of contamination → $C_d$ less than 8;
Slight extent of contamination → $C_d$ greater than 8 but less than 16;
Significant extent of contamination → Cd greater than 16 but less than 32;
Large extent of contamination → $C_d$ greater than 32[16].

**Pollution Load Index (PLI)**

Assessing the overall toxicity of soil concerning heavy metals can be achieved through the pollution load index (PLI). PLI was evaluated on the basis of method[17,12] as shown in equation (4):

$$PLI = [C_{f1} {}^{x}C_{f2} {}^{x}C_{f3} {}^{x}C_{f4} \ldots\ldots C_{fn}]^{1/n} \quad (4)$$

Here, $C_f$= contamination factor;
n = count of metals examined.

With reference to the PLI value soil quality categorized as:

Good quality → PLI < 1;
Significant level of pollutants → PLI = 1 and
Degradation of soil quality → PLI > 1[18].

## RESULTS AND DISCUSSION

To detect the contamination in the soil around the brick kiln, a comparison is made between the data obtained in the before-monsoon and after-monsoon seasons. To ascertain the contamination-level in soil adjacent to brick kiln, collected data were assessed in relation to the world-soil average value given by Kabata-Pendia[19] and the prescribed safe limit by the World- Health Organization or Food and Agriculture Organization (WHO/FAO)[20].

**Heavy metal content**

Table 2 demonstrates the average heavy metal content in examined soil of all sampling areas in before-monsoon and after-monsoon seasons.

From the result of concentration, it is observed that the average metal concentrations, except for Fe (in some cases), in each sampling area in after-monsoon season are greater than that of before-monsoon season.

**Table 2: Mean concentrations of Iron (Fe), Chromium (Cr), Cadmium (Cd), Lead (Pb), Zinc (Zn) and Copper (Cu) in sampling areas**

| Sampling areas | Mean Iron) Concentrations (mg/kg | | Mean Lead Concentrations (mg/kg) | | Mean Chromium Concentrations (mg/kg) | | Mean Cadmium Concentrations (mg/kg) | | Mean Zinc Concentrations (mg/kg) | | Mean Copper Concentrations (mg/kg) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | before-Monsoon | after-Monsoon | before-Monsoon | after-Monsoon | before-Monsoon | after-Monsoon | before-Monsoon | after-Monsoon | before-Monsoon | after-Monsoon | before-Monsoon | after-Monsoon |
| BKC1 | 10484 | 8960 | 18.33 | 19.68 | 17.28 | 20.74 | < 1 | < 1 | 33.54 | 34.9 | 35.22 | 39.4 |
| BKC2 | 19644 | 12340 | 38.4 | 39.75 | 37.35 | 44.82 | < 1 | < 1 | 70.27 | 71.6 | 73.78 | 82.6 |
| BKC3 | 13376 | 14500 | 49.1 | 50.45 | 48.05 | 57.66 | < 1 | < 1 | 89.85 | 91.2 | 94.34 | 105.7 |
| BKC4 | 7845 | 6900 | 24.35 | 25.7 | 23.3 | 27.96 | < 1 | < 1 | 44.56 | 45.9 | 46.78 | 52.4 |
| BKC5 | 8944 | 7700 | 37.9 | 39.25 | 36.85 | 44.22 | < 1 | < 1 | 69.35 | 70.7 | 72.82 | 81.6 |
| BKC6 | 11022 | 8800 | 68.4 | 69.75 | 67.35 | 80.82 | < 1 | < 1 | 125.17 | 126.5 | 131.43 | 147.2 |
| WHO/FAO* | - | | 85 | | - | | 0.8 | | 50 | | 36 | |
| World-Soil Average** | - | | 27 | | 59.5 | | 0.41 | | 70 | | 38.9 | |

* World Health Organization/ Food and Agriculture Standard of safe limit of heavy metals concentrations in soil.
** Evaluated average mean for the world scale of non-polluted soil given by Kabata-Pendias.

It is evident from the outcome of concentrations that metals in all sampling areas of both the seasons after- monsoon and before-monsoon followed the sequence-Cd<Pb<Cr<Zn <Cu<Fe and Cd<Cr<Pb<Zn<Cu<Fe respectively. It means, in both the seasons (before-monsoon and after-monsoon) across all types of sampling areas, Fe shows the maximum average concentrations while Cd shows the least.

The mean concentrations of Fe in sampling areas in the before-monsoon and the after-monsoon season were lies between 7845 to 19644 mg/kg and 6900 to 14500 mg/kg, respectively. Mean Fe content in all sampling areas was less than the safe limit of (40000mg/kg)[21] as shown in Figure 1.

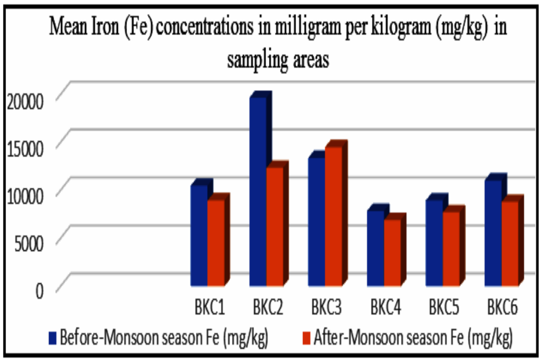


**Fig. 1. Mean concentrations of Iron (Fe) in sampling areas in both the seasons (before-monsoon and after-monsoon)**

The average concentrations of Pb in sampling areas during before-monsoon and after-monsoon seasons ranged from 17.28 to 67.35 mg/kg and 19.68 to 69.75 mg/kg, respectively (Fig. 2). The observed average concentrations of Pb were less than the safe limit of the WHO/FAO standard[20], but in some sampling areas, they exceeded, the evaluated world-soil average of 27.00 mg/kg[19] and the safe limit of 50 mg/kg[21]. The average Cr concentrations in sampling areas in before-monsoon lies between 21.38 to 62.35 mg/kg and after the monsoon season showed variation from 20.74 to 80.82 mg/kg, as shown in Fig. 2. In some sampling areas the observed mean concentrations of Cr were less than the world-soil average but in some areas the observed concentrations exceeded, the world -soil average of 59.50 mg/kg[19] and the safe limit of 47 mg/kg[21]; similar observation was also reported earlier in India by Mithra *et al.,*[22] and Iqbal *et al.,*[23] Observed mean concentrations of Cd in each sampling area in both the season before and after-monsoon were less than the permissible value of the WHO/FAO standard[20]. Although, these concentrations were very less even not detected by AAS. The mean Zn concentrations, before and after the monsoon season were varied from 33.54 to 117.02 mg/kg and 42.4 to 125.17 mg/kg, respectively (Fig. 2). In some sampling areas the observed concentrations, were higher than the permissible limit of the WHO/FAO standard[20], safe limit of 100 mg/kg[21] and also greater than the evaluated world average of unpolluted soil i.e., 70 mg/kg[19]. In sampling areas, the mean concentrations of Cu before and after the monsoon season were ranged from 35.22 to 131.43 mg/kg and 39.4 to 147.2 mg/kg, respectively (Fig. 2). The observed values, were greater than the safe limit of the WHO/FAO standard[20] as well as the evaluated world average of non-polluted soil (38.9 mg/kg)[19].

Since there have been few scientific investigations on soil pollution by heavy metals in the vicinity of the brick kiln, it is challenging to put the observed findings of this study into context. Therefore, the average concentrations (mg/kg) of metals in brick kiln soil (this work) were also compared to those of the average concentrations (mg/kg) of metals in soils from different regions of the world and in the upper crust with the appropriate references. The mean concentrations of Pb, Zn, and Cu in brick kiln soil were greater than the upper crust[24]. In both the seasons, the mean concentration of Pb in soil nearby brick kiln (this study) is higher than Iran[25,26], Portugal[27], Turkey[28], and lower than Italy[29] and lead/zinc smelter of China[30]. The mean Cadmium content in brick kiln soil (present study) is comparable with that of Iran[31], Italy[29], Turkey[28] and Portugal[27] but lower than the lead/zinc smelter of China[30]. In the brick kiln soil of the present study, the mean concentrations of Zn and Cu were higher than those for other parts of the world, i.e., higher than Iran[31], Portugal[27] and China[32], but lower than Italy[29] and Turkey[28]. In this study, the mean Pb and Cr content was relatively high as compared to the value observed for brick kilns located in Bangladesh[33].

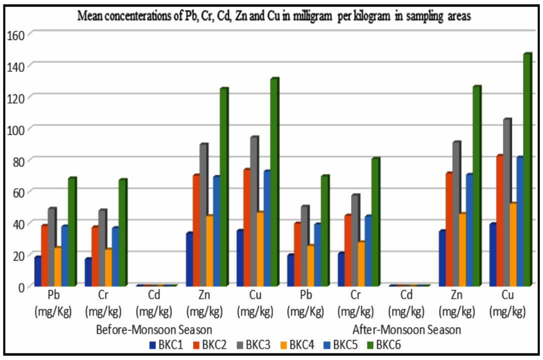


**Fig. 2. Mean concentrations of Lead (Pb), Chromium (Cr), Cadmium (Cd), Zinc (Zn) and Copper (Cu) in sampling areas in both the seasons (before-monsoon and after-monsoon)**

From the data of trace metal concentrations, it is observed that the average content of Cu, Pb, Cr and Zn in the soils was greater relative to the evaluated average mean for the world scale of non-polluted soil given by Kabata-Pendias[19].

**Metal pollution determination in soil**

Figure 3 represent the $I_{geo}$ value of heavy metals in soil of all the sampling areas in both the seasons. Before-monsoon soil around the brick kiln had a Cu $I_{geo}$ value, varied from -0.9384 to 0.961335 and after the monsoon varied from -0.77669 to 1.124818, which implies that before-monsoon season the site ranges from non-polluted to slightly polluted and after the monsoon season the site was slightly polluted with copper. The Pb $I_{geo}$ value of the sampling areas in before-monsoon and after-monsoon seasons varied from -0.71076 to 1.189034 and -0.60823 to 1.217231, respectively.

In both the seasons, the soil around brick kiln was slightly polluted with lead. The other metals (Fe, Cr and Zn) had $I_{geo}$ values less than zero in both seasons indicating the site was non-polluted. In both the seasons, the result of the contamination factor as shown in Fig. 4 represents minimal contamination for all the metals in the various sites except Pb and Cu. For Cu and Pb slight contamination was recorded in soil around brick kiln in both seasons.

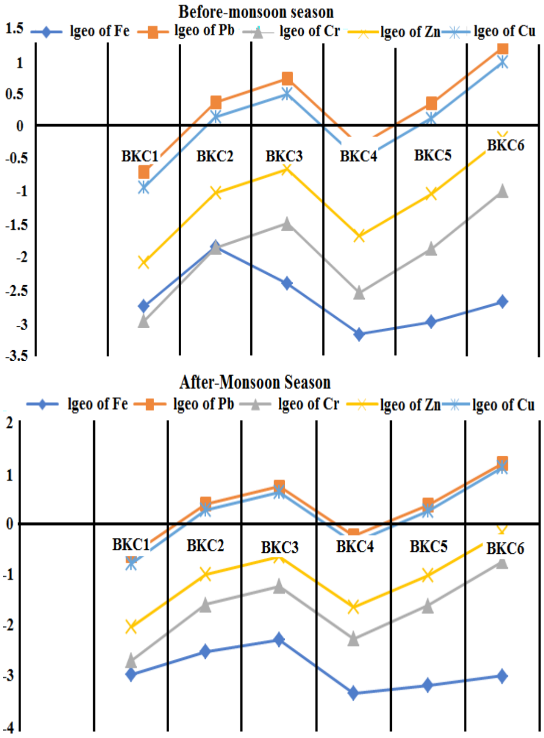


**Fig. 3. Heavy metals geo-accumulation index ($I_{geo}$) value in soil of sampling area in both the seasons (before and after the monsoon)**

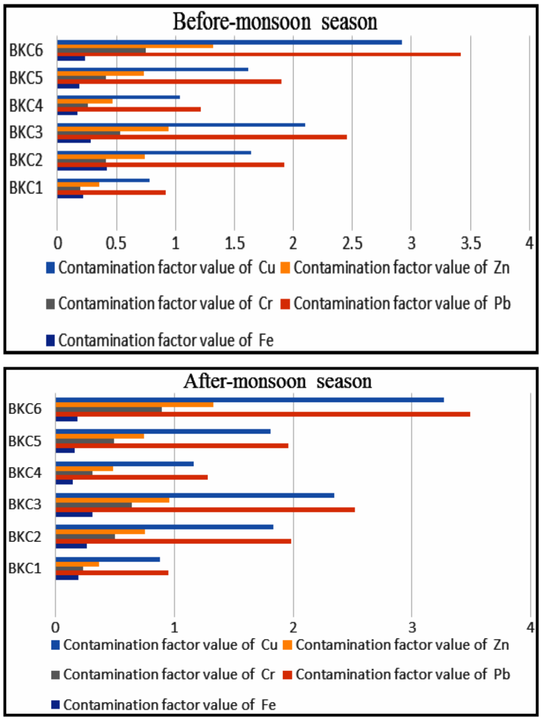


**Fig. 4. Heavy metals contamination factor ($C_f$) in soils of sampling areas in both the seasons (before-monsoon and after-monsoon)**

Less degree of contamination (Cd<8) was noticed for all the metals in different areas in both the seasons. The pollution load index value was greater than 1 at one sampling site (BKC6) in the post monsoon season while at other sites, the PLI value was less than 1 in both seasons. The pollution load data indicated that the soil of all the sampling areas shows perfection except BKC6 where soil quality is deteriorated. In order to protect human health, environmental sustainability, and the general well-being of surrounding populations, it is imperative to examine heavy metal poisoning in these locations.

## CONCLUSION

From the concentrations data of this research, it is found that the average heavy metals content in each sampling area was greater in the after-monsoon season relative to the before-monsoon and the mean of heavy metals concentrations were present in the sequence prescribed as: Cd<Pb<Cr<Zn<Cu<Fe in after-monsoon and Cd<Cr<Pb<Zn<Cu<Fe in the before-monsoon. This research highlights that the average concentrations of Zn, Cr and Cu in sampling areas were greater than the calculated world average of unpolluted soil and also exceeded the safe limit of the WHO/FAO standard. Mean concentrations of Cd in all sampling areas were within the safe limit. But the mean concentrations of Pb in each sampling area were lower than the safe limit of the WHO/FAO standard but exceeded the evaluated world average of non-polluted soil. Pollution indices data indicated that the soil around brick kiln was moderately polluted with copper and lead. PLI value of the present study indicating the gradual degradation of soil as a result of metal contamination. The research discovered that brick kilns are significantly polluting the soil in the examined area. This study suggested that the government should devise plans and policies to diminish the emission of heavy metals from brick kiln operations.

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**Conflict of Interest**

The authors declare that they have no conflict of interest.

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