Nep J Environ Sci (2021), 9(1), 01-10
https://doi.org/10.3126/njes.v9i1.34918

ISSN 2350-8647 (Print) 2542-2901 (Online)

Research Article

Impacts of brick kiln emission on agricultural soil around brick kiln areas

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(Received: 12 February 2021; Revised: 26 June 2021; Accepted: 27 June 2021)

Abstract

The study attempted to assess the impacts of the brick kilns emissions on the farm soil in and around the kiln areas. A total of 72 representative farm soil samples were collected from 12 selected brick kiln clusters in Rajshahi and Gazipur Districts of Bangladesh, covering two years (September 2015 to August 2017). The collected samples were analyzed using standard methods. The pH and organic matter content in the farm soil samples were found to be very low. The farm soil parameters such as pH, organic matter, and soil texture were found in critical conditions. Among all of the heavy metals, only Cr exceeded the permissible standard of some soil samples. The concentration of Cr ion varied from 9.50 to 52.77 and 16.54 to 70.13 ppm in Rajshahi and Gazipur Districts, respectively indicated the chance of metal contamination in plants. The study results showed that the values of contamination factor (C^i_f) and ecological risk factor (E^i_r) in the selected farm soil of Rajshahi and Gazipur Districts existed in the order of Cd > As > Cr > Pb > Zn and Cd > As > Pb > Cr > Zn, respectively. The study results also showed that the pollution load index and risk index values were lower than 1 and 150, respectively, at all sampling locations indicating lower pollution and risk from heavy metals in the areas. The study observed that continuous brick production over the periods degraded topsoil fertility and reduced agricultural productivity.

Keywords: Brick kiln, heavy metals, impacts, soil pollution, toxic

Introduction

The unplanned and mushroom growth of ill-constructed brick kilns in Bangladesh has become a threat to the environment. Various industries discharged or emitted several toxic elements, including organic load, inorganic matter, dissolved, suspended solids, heavy metals, and salt residues to the surface (soil), and water caused severe environmental pollution (Chowdhury et al., 2013). Hazardous pollutants may originate in the soils around the kiln areas from various sources, i.e., coal, wood, and furnace oil burning, use of tires for initial firing in the brick kiln areas. The hazardous pollutants, including heavy metals, CO, CO_2, SO_2, nitrogen oxides, and volatile organic compounds, are of great concern due to their wide-ranging sources, toxicity, non-biodegradable properties, and accumulative behaviors. So, the brick kilns are the source of cause's soil pollution. Industrial waste contains heavy metals that degraded the soil, water as well as aquatic life. Soil erosion and industrial waste deposal to agricultural lands in Bangladesh have threatened heavy metals contamination, causing a significant health hazard for humans (Helal et al., 2011). The fly ash produced as a byproduct of a brick kiln is disposed of in the form of ash slurry into the surrounding land, water body, vegetation, etc. The fly ash and surface run-off contaminated water from the kilns areas indisputably decline soil fertility and crop production in the surrounding agricultural lands. Different types of heavy metal pollution occur due to brick kiln activities. These toxic metal ions and their compounds caused extremely harmful to human health. So, it is a matter of concern that toxic metal ions can make the organometallic compounds with the organic functional groups. Finally, the organometallic compounds are consumed by humans through foodstuffs, which may cause several health problems for humans. Three-quarters of the world's soil degradation occurs in tropical areas, and about 7% of the total land area (13,391 km^2) of the country is experiencing land degradation where the loss through the brick kilns was not considered (Eswaran, 1999).

The brick kilns in Bangladesh emit around 6 million tons of CO_2 annually, making it one of the largest sources of greenhouse gas emissions in the country. The continued use of this outdated brick-firing technology would raise the level of greenhouse gas emissions to 8.7 million tons by 2014 if Bangladesh maintains its current economic growth rate (Saha et al., 2020). The brick sector consumes a large amount of the top layer of agricultural soil per year. It is observed that many holes of nearby areas of the brick kiln are left abandoned by owners after collecting the top fertile soil. The topsoil of fertile lands is strictly prohibited for use in brick production. But a matter of concern that the

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Nep J Environ Sci (2021), 9(1), 01-10
https://doi.org/10.3126/njes.v9i1.34918

direction frequently violated, resulting in soil nutrition's are losing day by day. Hassan et al. (2012) reported that the brick burning process was not only changing the physicochemical properties and habitats of the soils but also producing environmental pollution. Continuous brick making over the periods degraded the topsoil fertility and reduced agricultural productivity. It disposed of dust, emitted heat, and destroyed the soil biota around the kiln areas (Gupta & Narayan, 2010). Budhwar et al. (2006) studied the effect of brickworks emissions on the heavy metal content of soil and plants around the brick kiln chimneys. Soil burning activity in the brick kiln decreases the soil pH making it acidic, increase sand, and decrease the clay content. It has severe impacts on soil physical, biological, and chemical properties resulting in a sharp declination in soil fertility and productivity. Besides, it removes organic matter and makes the soil unfit for crop cultivation (Thapa, 2011). There is still no detailed information on the brick kiln emissions and assessing the potentiality of toxic gases and elements from kilns and their effects on farm soil. However, most of these studies are conducted near greater Dhaka; moreover, there is no report available for the other brick kilns areas. The main objective of the study was to assess the impacts of brick kiln emissions on the farm soil around the kiln areas. The study focused on the toxic heavy metals on the soils around the brick kiln areas and assessed pollution load index and ecological risk factors.

Materials and Methods

Study Area

The study was carried out in twelve (12) selected brick kiln clusters in Rajshahi and Gazipur Districts of Bangladesh (Fig. 1). The samples were collected thrice in a year, namely as i) pre-production season (September - December), ii) production season (January – April), and iii) post-production season (May-August). A total of 72 farm soil samples were collected during the pre-production, production, and post-production season over the years from September 2015 to August 2017. Of them, 48 were collected from 8 sampling locations in Rajshahi, and 24 samples were collected from four (4) sampling locations in Gazipur Districts, respectively.

Farm soil samples were collected at a depth of 0 -15 cm for laboratory analysis. Before the collection of the sample, un-decomposed organic matter was carefully removed without disturbing the topsoil. Each sample was kept separately on brown paper. The contents of each brown paper were mixed thoroughly, and then about 500 gm of soil was collected from each paper to give a representative sample. Samples were placed in sealed polythene bags and labeled bags and kept carefully to avoid any damage. Then the samples were air-dried for seven days. After it mixed and grinned well, and ground to pass through a 10-mesh sieve. The samples were kept in a polythene packet for chemical analysis.

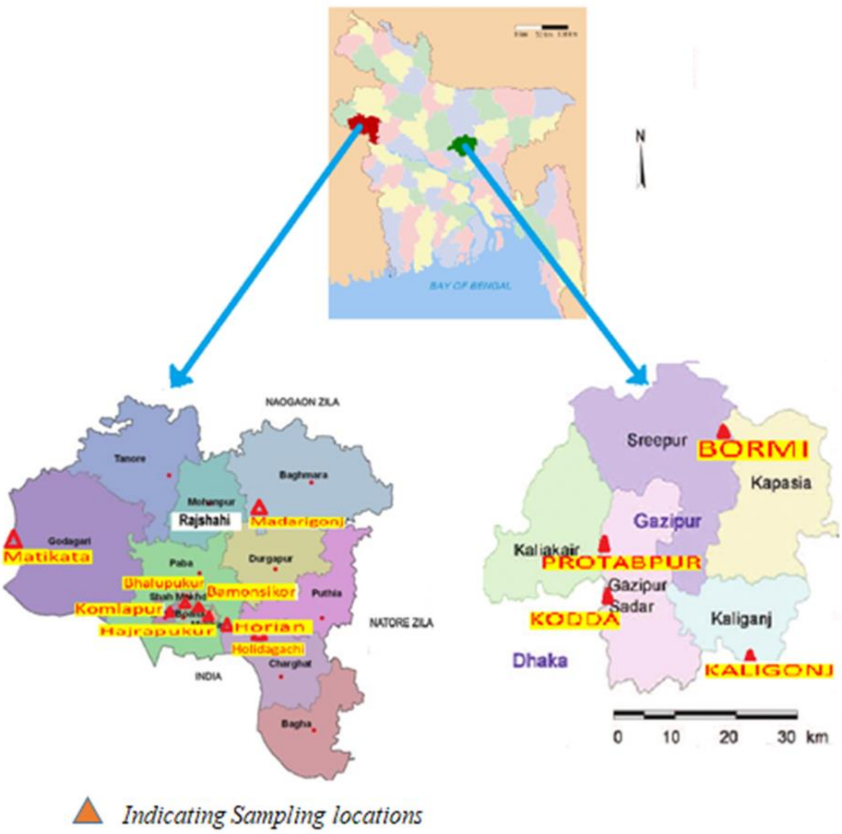

Figure 1 Sampling locations map of Rajshahi and Gazipur district.

Nep J Environ Sci (2021), 9(1), 01-10
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The samples were analyzed using standard analysis methods using different precious instruments, including electrical conductivity meter, glass electrode pH meter, atomic absorption spectrophotometer, etc. Several analysis methods, including conventional and standard scientific methods like Jackson (1985) for soil pH, Gosh et al., (1983) for organic matter, Bouyoucos (1927) for soil texture, Adams (1991) for digestion of soil samples analysis by using AAS. The study also conducted pollution load index and risk index of heavy metals in the farm soil using the Hakanson method (Hakanson, 1980).

Assessment of Pollution Load Index and Risk Index

The study was conducted to achieve the pollution load index and risk index of heavy metals in the farm soil using the Hakanson method (Hakanson, 1980). The computing equation for contamination factor (C^i_f) and the degree of contamination (C_d) are as follows:

$$C^i_f = C^i / C^i_n \qquad (1)$$
$$C_d = \sum_{i=1}^{n} C^i_f \qquad (2)$$

Where C^i is the measured concentration of the heavy metals in farm soil and C^i_n is the standard pre-industrial reference level (in ppm): 70 for Pb, 1.0 for Cd, 90 for Cr, 50 for Cu, 175 for Zn, 850 for Mn (Hakanson, 1980).

The contamination factor and degree of contamination were classified into four groups, and their values are C^i_f <1, 1≤ C^i_f <3, 3≤ C^i_f <6, and $C^i_f \geq 6$ indicate low, moderate, considerable, and very high contamination factors, respectively. The degree of contamination defines the quality of the environment in the following way: C_d < 8, 8≤ C_d <16, 16≤ C_d <32, and $C_d \geq 32$ indicated low, moderate, considerable, and very high degree of contamination accordingly.

Pollution Load Index (PLI)

The extents of pollution by the heavy metals were assessed by employing the method based on the pollution load index (*PLI*) developed by Tomlinson et al., (1980), and the expression is shown below:

$$PLI = (C_{f1} \times C_{f2} \times C_{f3} \times \ldots\ldots\ldots \times C_{fn})^{1/n} \qquad (3)$$

Where n is the number of metals (n = 5 in this study), and C_f is the contamination factor. Thus, *PLI* provides a simple, comparative means for assessing a site or estuarine quality: a value of zero indicates perfection, a value of one indicates only baseline levels of the pollutants present, and values higher than one would indicate progressive deterioration of the site and estuarine quality (Tomlinson et al., 1980).

Risk Index

The potential ecological risk factor (E^i_r) of a single element and the potential ecological risk index (*RI*) of multi-element can be computed by the following equations (Hakanson, 1980):

$$E^i_r = T^i_r \times C^i_f \qquad (4)$$
$$RI = \sum_{i=1}^{n} E^i_r \qquad (5)$$

Where, C^i_f is the contamination factor for the element of "*i*"; T^i_r is the toxic-response factor for the given element of "*i*", which accounts for the toxic requirement and sensitivity requirement.

The toxic-response factors for Cr, Mn, Cd, Zn, and Pb were 2, 1, 30, 1, and 5, respectively (Hakanson, 1980). The grading standards of potential ecological risk and ecological risk level of single-factor pollution of heavy metals were E^i_f < 40, 40 ≤ E^i_f < 80, 80 ≤ E^i_f < 160, 160 ≤ E^i_f < 320, and 320 ≤ E^i_f indicated low, moderate, higher, serious, and extreme, respectively. The relationship between potential toxicity index (*RI*) and general level of potential ecological risk was *RI* < 150, 150≤ *RI* <300, 300 ≤ *RI* < 600, and 600 ≤ *RI* indicated low, moderate, higher, and extreme, respectively.

The experimental data analyzed with scientific software like MS Excel 2013. Statistical measurements such as maximum, minimum, mean, and standard deviation values were calculated for categorization and describing the variables.

Results and Discussion

The farm soil samples were analyzed for some major physicochemical parameters, including heavy metals. The analyzed results are discussed in the following:

Physicochemical Parameters

The farm soil samples were analyzed for some major physicochemical parameters, such as electrical conductivity, pH, organic matter, and soil texture. Unfortunately, there are no available standards of the above parameters, and therefore the observations of some published reports were cited here to evaluate the soil status.

Electrical Conductivity (EC)

The electrical conductivity (EC) indicated the amount of soluble (salt) ions in the soil, and it is an important indicator of soil health. It affects crop yields, crop suitability, and plant nutrient availability. Generally, the EC of the soils varied markedly with soil salinity. The analysis results showed that the EC of collected farm soil samples was ranged from 165 to 391 μS/cm in Rajshahi and 222 to 453 μS/cm in Gazipur (Table 1). Agricultural practices like fertilization, irrigation, etc., helped the accumulation of cations in the farm soils. However, the brick kiln activities such as sand and brick dust reduced cationic content in the soil. Hence, it seems to be responsible for the lower EC values in the production season. The EC value of farm soil samples in the study area followed in the order: pre-production season> post-production season > production season. Research conducted on the status of different nutrients in soil samples reported that most of the nutrients and EC values were comparatively higher in the agricultural field than those of brickfield soils (Salek, 2007).

pH

Soil pH or soil reaction indicates the acidity or alkalinity of soil and is measured in pH units. Soil pH is important as it influences several soil factors affecting plant growth, such as

Nep J Environ Sci (2021), 9(1), 01-10
https://doi.org/10.3126/njes.v9i1.34918

soil bacteria, nutrient leaching, nutrient availability, toxic elements, and soil structure, etc. The results showed that the pH values of collected farm soil samples were ranged from 6.18 to 8.29 in Rajshahi and 6.60 to 8.48 in Gazipur (Table 1). The pH of some farm soil samples was a critical condition for crop production (Halvin et al., 2004). The pH value of farm soil samples is followed in the order: pre-production season> post-production season > production season. Greentech (2012) reported that the brick kilns emitted toxic pollutants containing sulfur dioxide (SO_2), oxides of nitrogen (NO_X), and other different gaseous compounds (Greentech Knowledge Solutions, 2012). These compounds might be responsible for the deterioration of the air quality and acid rain syndrome surrounding the brick kiln areas, which hamper the soil pH.

Organic Matter (OM)

The soil organic matter consists of various components in varying proportions and many intermediate stages, an active organic fraction, including microorganisms and organic matter. The organic matter of the soil has potential effects on soil fertility, moisture, and the development of flora. The results showed that the organic matter content in the collective farm soil samples was ranged from 0.58 to 3.21% in Rajshahi and 0.34 to 1.47% in Gazipur (Table 1). The concentration of organic matter in the collected soil samples was found to be very low. The organic matter content in the production season was found lower compared to other seasons. The overall OM content of farm soil samples in the study area followed in the order: pre-production season> post-production season> pre-production season. Low-level OM content in the production season may be due to the burning of organic carbon in the brick kiln, extreme heat in the kiln area, and the topsoil removal process. The lower values of organic matter (OM) and organic carbon in the soil were responsible for the lower cation exchange, water holding capacity, and buffering properties of the soil. It is susceptible to soil erosion and reduced microbial activities (Van Loon, 2007).

Table 1 Biyearly descriptive statistics of physicochemical parameters in farm soil from September 2015-August 2017

Physicochemical parameters	Study area	Minimum	Maximum	Mean ± SD
Electrical Conductivity (µS/cm)	Rajshahi	165	391	256.96 ± 59.78
	Gazipur	222	453	332.71 ± 63.71
pH	Rajshahi	6.18	8.29	7.67 ± 0.46
(Water: soil ratio:2.5:1)	Gazipur	6.60	8.48	7.44 ± 0.50
Organic matter (%)	Rajshahi	0.58	3.21	1.51 ± 0.49
	Gazipur	0.34	1.47	0.93 ± 0.32

Soil Texture

The soil texture and its vertical spatial heterogeneity may greatly influence soil hydraulic properties and the distribution of water and solutes in the soil profile. Therefore, the soils are of great importance for agricultural, environmental, and geoengineering applications. The relative percentages of sand, silt, and clay soil were determined by the mechanical analysis process to find the textural classes. The data on the particle size distribution of the farm soil was collected at a depth of 0-15 cm. The results showed that the farm soil samples contain more than 50% sand particles in the production season (Figures 2 & 3). The silt and clay particle proportion were found very low in the production and post-production seasons compared to the pre-production season. The highest value of the sand particles was found to be 83.64% and 88.64% at Kodda in Gazipur in the production season from September 2015 - August 2017, respectively (Not shown in Table). The study observed that the textural class turned to more sandy conditions in the production season compared to other seasons. The soil texture might be varied at different sampling locations depending on the region and age of the soil. During the brick-making process, a huge amount of dust was generated from the kilns that cause environmental degradation and disrupted the soil texture. The soil profile around the brick kiln areas might be affected due to rainfall and other seasonal effects along with brick production. A report showed that the soil texture might be affected by the wind erosion that produced dust around the brick kiln (Abuduwaili & Mu, 2002). The analysis results of the farm soil profile showed that the yearly average sand content in the soil increased, while the silt and clay contents decreased (Table 2). A report showed that the degradation of agricultural soils is associated with brick burning (40 to 100°C) based on soil profile studies of soil around the brick kilns and agricultural lands in some districts of the Dhaka division (Khan et al., 2007). The average sand content of the soil profiles increased by 24.5%, while the silt and clay contents decreased by 4.2% and 3.6%, respectively. Under changing environmental conditions, the soil particles, i.e., sand, silt, and clay bound heavy metals like Pb, Cr, As, etc., may exhibit extreme toxicity even at low levels under certain conditions (Peerzada et al., 1990).

Heavy Metals in Farm Soil

A study reported that heavy metals in excessive amounts in soil, water, and air lead to several health problems, including neurotoxicity, kidney toxicity, sterility, anemia, etc. (Islam & Mostafa, 2020). The study analyzed heavy metals, namely Pb, Cr, Cd, As, Fe, and Zn in the farm soils in the pre-production, production, and post-production seasons from September 2015 to August 2017. The analyzed results were compared with the standard permissible limit of these parameters and are described below:

Nep J Environ Sci (2021), 9(1), 01-10
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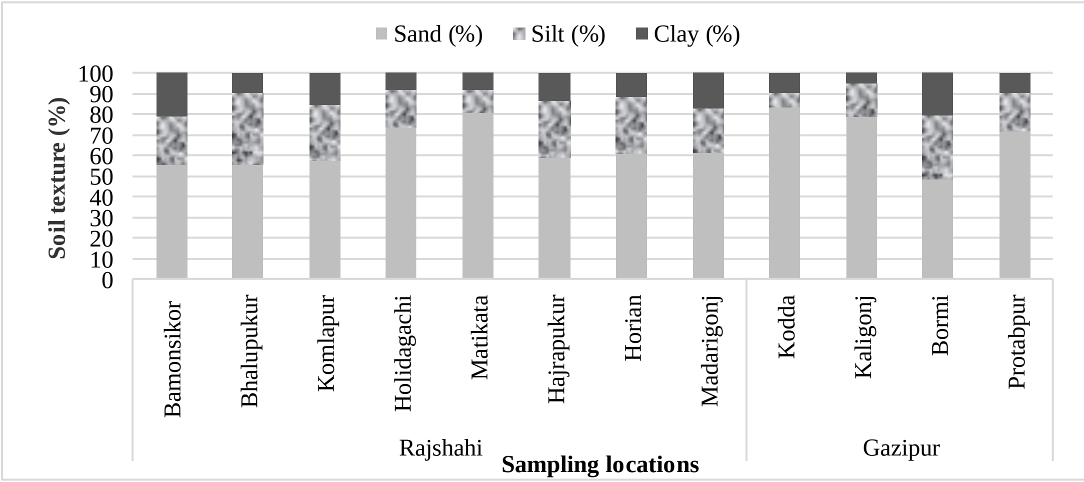

Figure 2 Comparative study of the textural class of farm soil at different locations during January - April 2016.

Table 2 Variation of textural class of farm soil from September 2015 – August 2017

Study area	Yearly duration (September – August)	Particle size distribution								
		Pre-production season			Production season			Post-production season		
		Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)
Rajshahi	2015 – 2016	45.39	36.63	17.98	63.01	23.88	13.11	53.64	29.00	17.36
Rajshahi	2016 – 2017	51.89	29.75	18.36	67.01	21.00	11.99	56.76	27.88	15.36
Gazipur	2015 – 2016	50.64	26.00	23.36	70.64	18.25	11.11	60.39	23.50	16.11
Gazipur	2016 – 2017	65.89	19.50	14.61	77.14	14.25	8.61	65.14	22.25	12.61

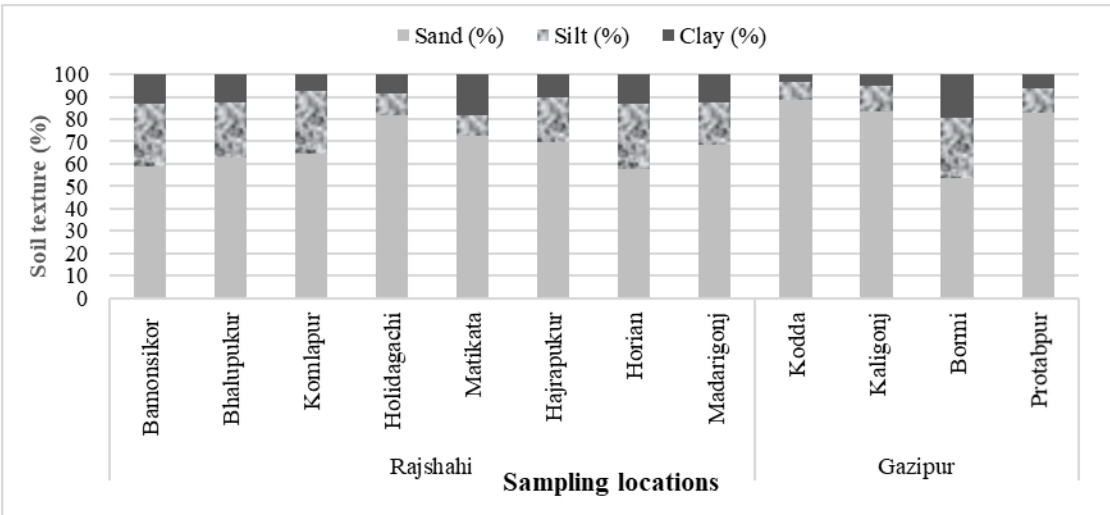

Figure 3 Comparative study of the textural class of farm soil at different locations during January - April 2017.

Lead (Pb)

The lead (Pb) is an extremely toxic heavy metal that disturbs various plant physiological processes and damages lipid membrane leading to the damage of chlorophyll and photosynthesis process and suppresses the overall growth of the plant (Najeeb & Ahmad, 2014). The results showed that the Pb concentration in farm soil ranged from 9.53 to 31.27 ppm in Rajshahi and 9.54 to 23.86 ppm in Gazipur (Table 3). The bi-yearly mean concentration of Pb in the farm soil samples was 16.66 and 11.53 ppm in Rajshahi and Gazipur Districts, respectively (Figure 3). Bibi et al. (2003) stated that the mean Pb concentration of soils in different depths ranged between 19 - 24 ppm in Bangladesh (Bibi et al., 2003). A report showed that the Pb status of the soils was

Nep J Environ Sci (2021), 9(1), 01-10
https://doi.org/10.3126/njes.v9i1.34918

lower than the maximum acceptable limit of 100 ppm for crop production (Kabata & Pendias, 1992).

Chromium (Cr)

Chromium (Cr) enters various environmental matrices (air, water, soil) from a wide variety of natural and anthropogenic sources. Martin and Griswold (2009) reported that an extremely high dose of Cr compounds in humans has resulted in severe respiratory, cardiovascular, renal, and neurological effects. The Cr concentration of farm soil ranged from 9.50 to 52.77 ppm in Rajshahi and 16.54 to 70.13 ppm in Gazipur (Table 3). The bi-yearly mean concentration of Cr in the collected soil samples was 26.77 and 37.61 ppm in Rajshahi and Gazipur, respectively (Figure 4). A few numbers of samples at different locations contained Cr concentrations greater than 50 ppm, which exceeded the permissible standard. Kudesia (2009) stated that the low-grade coals usually used in the brick burning process might emit higher Cr concentration, which causes plant growth reduction, soil fertility loss, and some hazardous diseases of a human being (Kudesia, 1990).

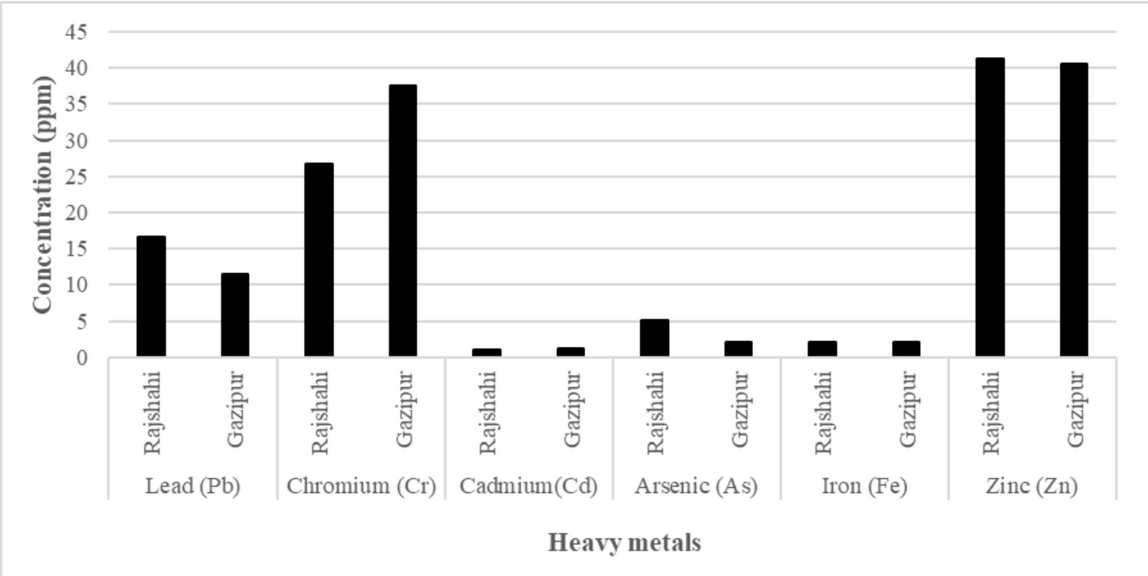

Figure 4 Biyearly average heavy metal concentration in farm soil from September 2015 to August 2017.

Cadmium (Cd)

Cadmium (Cd) is a heavy and very toxic metal. It naturally occurs in the soils and rocks, including coal and mineral fertilizers. Cadmium and cadmium compounds are known human carcinogens. Severe damage to the lungs may occur through breathing high levels of cadmium. Long-term exposure to lower levels leads to a buildup in the kidneys and possible kidney disease, lung damage, and fragile bones (Martin & Griswold, 2009). The study results showed that the Cd concentration in farm soil ranged from 0.42 to 1.95 ppm in Rajshahi and 0.91 to 1.85 ppm in Gazipur (Table 3). The bi-yearly mean concentration of Cd in the collected soil samples was 0.97 and 1.19 ppm in Rajshahi and Gazipur Districts, respectively (Figure 4). The results of this study indicated that all of the farm soil samples contained Cd concentration within the range (3.00 ppm) for the uncontaminated soil range.

Arsenic (As)

Arsenic is a metalloid and naturally occurring substance widely available on the Earth, i.e., water, air, and soil. The arsenic concentration in the farm soil ranged from 2.90 to 6.80 ppm in Rajshahi and 1.10 to 3.40 ppm in Gazipur (Table 3). The bi-yearly mean concentration of As in the collected soil samples was 5.01 and 2.02 ppm in Rajshahi and Gazipur districts, respectively (Figure 3). The study showed that the concentration of As in the Rajshahi region was higher than in the Gazipur region. A study was carried out on arsenic contamination at five different Agro-Ecological Zones (AEZ) in Bangladesh. It revealed that the concentration of As in the farm soil is higher and toxic in Rajshahi zones compared to the other zones (Al Mamun, 2009). The results of this study indicated that all the farm soil samples contained As within the range (20.00 ppm) for uncontaminated soil range.

Iron (Fe)

Iron can mention as a common metal and be present in the earth's crust. It is an unbelievably useful substance in the modern world. However, the increasing proportion is to be unsafe for humans and plants. The results showed that the iron (Fe) concentration in farm soil ranged from 1.12 to 3.03 ppm in Rajshahi and 1.59 to 2.81 ppm in Gazipur (Table 3). The bi-yearly mean concentration of Fe in the collected soil samples was 2.02 and 2.16 ppm in Rajshahi and Gazipur Districts, respectively (Figure 3). The extreme heat produced during brick-making operations may cause soil burning and textural disruption in the surrounding areas. Khan et al. (2007) reported that soil burning was found to decrease the average pH values of soils with the depth function. The low pH in the production season compared to the other seasons might be responsible for

Nep J Environ Sci (2021), 9(1), 01-10
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increasing the concentration of Fe in the production season. The results of this study indicated that all of the farm soil samples contained Fe concentration within the range of (10.00 ppm) for uncontaminated soil range.

Table 3 Biyearly descriptive statistics of heavy metal concentration in farm soil samples from September 2015 – August 2017

Heavy metals	Study area	Unit (ppm)			Permissible Standard
		Minimum	Maximum	Mean ± SD	
Lead (Pb)	Rajshahi	9.53	31.27	16.66 ± 5.81	100.00 ppm*
	Gazipur	6.54	23.86	11.53 ± 5.09	
Chromium (Cr)	Rajshahi	9.50	52.77	26.77 ± 12.22	50.00 ppm*
	Gazipur	16.54	70.13	37.61 ± 13.94	
Cadmium (Cd)	Rajshahi	0.42	1.95	0.97 ± 0.32	5.00 ppm*
	Gazipur	0.91	1.85	1.19 ± 0.24	
Arsenic (As)	Rajshahi	2.90	6.80	5.01 ± 0.91	50.00 ppm*
	Gazipur	1.10	3.40	2.02 ± 0.53	
Iron (Fe)	Rajshahi	1.12	3.03	2.02 ± 0.47	20000 – 550000 ppm**
	Gazipur	1.59	2.81	2.16 ± 0.34	
Zinc (Zn)	Rajshahi	12.68	79.34	41.23 ± 18.21	300.00 ppm*
	Gazipur	11.24	78.51	40.58 ± 20.41	

*Kabata and Pendias (1992); **Bodek et al. (1988).

Zinc (Zn)

Zinc (Zn) is a metal found in Earth's crust with untold industrial and biological values. Human and crop plants need Zn to act as a source of providing nutrition. However, if it present in higher concentration also acts highly toxic to flora and fauna. The zinc (Zn) concentration in farm soil ranged from 12.68 to 79.34 ppm in Rajshahi and 11.24 to 78.51 ppm in Gazipur (Table 3). The bi-yearly mean concentration of Zn in collected farm soil samples was 41.23 and 40.58 ppm in Rajshahi Gazipur, respectively (Figure 3). A report showed that soil burning caused the average pH decreased values of the soils with the depth function (Khan et al., 2007). The low pH in the production season might be responsible for increasing Zn concentration. The results of this study indicated that all of the farm soil samples contained Zn within the range (1.00-200.00 ppm). The concentration of several heavy metals at different locations varies might be attributed to the direction and velocity of wind, age of the topsoil, deposition concentration, etc. The selected heavy metal concentration in the farm soil samples followed in the order: production season> post-production season> pre-production season. The results showed that different heavy metal concentrations were higher in the production season compared to other seasons because the combusted residue of bricks and their blown fly ash contaminated the farm soil. The study observed that brick production is responsible for heavy metal contamination in farm soils. From that point of view, heavy metal contamination remains a threat in the future, despite the present situation yet to reach an alarming state for any agricultural crop production.

Pollution Load Index

The analysis results of the contamination factor (C^i_f), the degree of contamination (*Cd*), and pollution load index (*PLI*) of heavy metals in the farm soils of different sampling locations of Rajshahi and Gazipur Districts in the pre-production, production, and post-production seasons from September 2015 - August 2017 are summarized in Table 4. The mean contamination factor (C^i_f) of As, Cr, Pb, and Zn was found below 1, except for the Cd in both study areas. Most of the value of the mean contamination factor of Cd was greater than one (1) indicated that the soils were moderately contaminated. The contamination factor (C^i_f) in the selected farm soil of Rajshahi and Gazipur Districts existed in the order of Cd > As > Cr > Pb > Zn. The study results showed that a lower degree of contamination ($Cd < 8$) was found in all sampling locations. It also showed that the *PLI* values were lower than one (1) in all sampling locations, indicating lower pollution occurred in the areas (not shown in the Table). A study on geochemistry of groundwater illustrated that the anions and cations were found higher-level during the brick production season. It is difficult to control the dissolution of undesirable constituents in the waters once they enter the soils (Mostafa et al., 2017). A study conducted on the impacts of industrial effluents revealed that heavy metals contamination in the industrial areas showed a higher-level pollution load index, and it depends on the discharged waste quality and quantity (Chowdhury et al., 2015).

Risk Index

The analysis results of the potential ecological risk factor and risk index of heavy metals in the farm soil of different sampling locations Rajshahi and Gazipur Districts in the pre-production, production, and post-production seasons from September 2015 to August 2017 are summarized in Table 5. The ecological risk factors (E^i_r) of Pb, Cr, Cd, As, and Zn in both study areas found lower than 40, which belong to low ecological risk, except Cd. The overall ecological risk factor (E^i_r) in the selected farm soil of Rajshahi and Gazipur districts existed in the order of Cd > As > Pb > Cr > Zn. A few numbers of samples showed the Cd value greater than 40 indicated a moderately ecological

Nep J Environ Sci (2021), 9(1), 01-10
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risk factor with Cd in some sampling locations. All the sampling sites were at a low-risk level where the *RI* values were much lower than 150, indicating a low-risk index. The results indicated a lower potential ecological risk and the risk index posed by the heavy metals at different sampling locations (not shown in the Table). A study conducted on the impacts of industrial effluents on the soil in BSCIC, Rajshahi revealed that heavy metals contamination in the industrial areas found to be a low-risk index. The observation supported the present finding (Hossain, 2018).

Table 4 Contamination factors (C_f^i), degree of contamination (C_d), and pollution load index (*PLI)* of heavy metals in farm soil from September 2015 - August 2017

Duration	Study area	Contamination factors (C_f^i)					Degree of contamination (C_d)	Contamination level	Pollution load index (*PLI*)
		Pb	Cr	Cd	As	Zn			
Pre-production season, 2015	Rajshahi	0.154	0.170	1.012	0.338	0.096	1.771	Low	0.024
	Gazipur	0.102	0.259	1.050	0.136	0.090	1.637	Low	0.199
Production season, 2016	Rajshahi	0.321	0.428	0.890	0.362	0.307	2.310	Low	0.418
	Gazipur	0.252	0.565	1.087	0.125	0.380	2.410	Low	0.371
Post-production season, 2016	Rajshahi	0.219	0.269	1.097	0.314	0.287	2.187	Low	0.353
	Gazipur	0.135	0.400	1.270	0.141	0.276	2.223	Low	0.303
Pre-production season, 2016	Rajshahi	0.167	0.166	0.789	0.330	0.104	1.550	Low	0.231
	Gazipur	0.111	0.269	1.325	0.121	0.092	1.919	Low	0.209
Production season, 2017	Rajshahi	0.336	0.463	0.970	0.337	0.320	2.426	Low	0.434
	Gazipur	0.261	0.591	1.115	0.132	0.272	2.370	Low	0.358
Post-production season, 2017	Rajshahi	0.236	0.289	1.096	0.320	0.295	2.229	Low	0.360
	Gazipur	0.141	0.419	1.287	0.153	0.279	2.279	Low	0.309

Impact on Farm Soil

Brick burning processes changed the physicochemical properties and habitats of the soils but also contributed to environmental pollution. The study results showed that the brick kilns are situated on fertile agricultural land. The topsoil of agricultural lands was used as a major brick-making raw material. Thus, excavating the topsoil cause the loss of fertile agricultural lands. Nusrat and Mahadev (1991) investigated the loss of soil fertility due to brick-making soil in Mysore in India. The brick manufacturers need good quality soils resulted in losing the land fertility and use the pattern.

Local political power also plays a crucial role in the brick production soil business. Thus, a large amount of topsoil of the fertile agricultural lands turned into unfertile. Khan et al. (2007) reported that the loss of soil fertility occurred due to brick production in different regions of Bangladesh (Khan et al., 2007). Nutrient elements like nitrogen, phosphorus, and potassium are essential for plant growth and crop yielding. The topsoil nutrient elements and soil biota are destroyed through brick burning. The brick burning process is a major contributor to emitting greenhouse gases into the atmosphere. Hence it is imperative to have a closer look into the brick kiln operating process for not allowing the topsoils in the brick-making process and controlling greenhouse gas emissions (IUSS, 2002). Mazumdar et al. (2018) reported that the brick burning emitted heat reduces the surrounding soil moisture. The brick kiln generates a large number of fly ashes from the combustion process. Fly ash produced as a byproduct of a brick kiln is disposed of as ash slurry into the surrounding land, waterbody, vegetation, etc. The fly ash and surface run-off contaminated water from the kilns areas indisputably decline soil fertility and crop production in the surrounding agricultural lands. The results showed that only Cr exceeded the permissible standard of some soil samples. The study revealed that firewood, coal, and petroleum were used as fuels in the brick burning process, which produced fly ashes that might be enriched with heavy metals in the production seasons at the kiln areas. Budhwar et al. (2006) studied the effect of brick kiln emitted heavy metals on the soil and plants around the brick kiln chimneys. Heavy metals like Pb, Cr are reported to have contaminated and reduced the soil quality and damaged the plant life (Maya et al., 2015). High concentrations of the toxic components in the soils with an acidic pH affected the plant community and posed a vital threat to human health (Ochieng et al., 2010). The brick kilns emit more smoke than any other factory because the burning process takes a long time to solidify the bricks from mud, and low-quality coal is burnt in this process, which caused more pollution.

Nep J Environ Sci (2021), 9(1), 01-10
https://doi.org/10.3126/njes.v9i1.34918

Table 5 Potential ecological risk factors (E^i_r) and risk index (*RI*) of heavy metals in farm soil samples from September 2015 - August 2017

Duration	Study area	Potential ecological risk factors (E^i_r)					Risk index (*RI*)	Pollution degree
		Pb	Cr	Cd	As	Zn		
Pre-production season, 2015	Rajshahi	0.771	0.340	30.37	3.383	0.097	34.966	Low
	Gazipur	0.691	0.395	30.72	2.762	0.095	34.665	Low
Production season, 2016	Rajshahi	1.610	0.857	26.70	3.625	0.308	33.100	Low
	Gazipur	1.504	0.941	28.52	2.894	0.330	34.193	Low
Post-production season, 2016	Rajshahi	1.098	0.539	32.92	3.150	0.287	37.998	Low
	Gazipur	0.969	0.620	34.58	2.616	0.284	39.006	Low
Pre-production season, 2016	Rajshahi	0.811	0.333	23.66	3.308	0.104	28.218	Low
	Gazipur	0.733	0.396	28.61	2.664	0.100	32.506	Low
Production season, 2017	Rajshahi	1.682	0.927	29.10	3.375	0.320	35.403	Low
	Gazipur	1.567	1.005	30.44	2.741	0.305	36.057	Low
Post-production season, 2017	Rajshahi	1.164	0.570	32.77	3.208	0.295	38.012	Low
	Gazipur	1.024	0.653	34.57	2.693	0.290	39.234	Low

Conclusion

A huge amount of farm soil is being used in brick making process every year in Bangladesh. The lead (Pb) and chromium (Cr) concentrations were found very high in the fly ash samples at different locations might have influenced the heavy metals pollutions in the soil and water. The pH and organic matter in the farm soil samples were found to be very low. The farm soil parameters such as pH, organic matter, and soil texture were found in critical conditions. Most of the farm soil samples contained more than 50% of sand particles in the production seasons. Among all the heavy metals, only Cr exceeded the permissible standard of some soil samples. The concentration of Cr ion varied from 9.50 to 52.77 and 16.54 to 70.13 ppm in Rajshahi and Gazipur, respectively. The study results showed that the values of contamination factor (C^i_f) and ecological risk factor (E^i_r) in the selected farm soil of Rajshahi and Gazipur districts existed in the order of Cd > As > Cr > Pb > Zn and Cd > As > Pb > Cr > Zn, respectively. The study results showed that pollution load index and risk index values were lower than 1 and 150, respectively, at all sampling locations, indicating low-level pollution and risk from heavy metals in the areas. Therefore, it can be said that continuous brick production over the periods degraded topsoil fertility and reduced agricultural productivity.

Acknowledgements: The authors would like to thank the Ministry of Science and Technology, Government of the People's Republic of Bangladesh for granting a partial fund.

Author Contributions: MKS: literature review, sample collection and analysis, primary manuscript draft, revision; RRS: primary draft preparation and sample analysis; SJA: research conceptualization, sample analysis, primary draft preparation, revision; AHS: research conceptualization, sample analysis, draft revision and finalization of the manuscript.

Conflict of Interest: The authors declare no conflict of interest.

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