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Impacts of Brick Kilns on Environment around Kiln areas of Bangladesh

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Abstract

The study aimed to assess the impacts of the brick kiln on the environment around the kiln areas. The study conducted a survey based on a structured questionnaire and sampling at selected 12 brick kiln clusters in Rajshahi and Gazipur Districts of Bangladesh. The sampling analysis results were compared with the national and international standard limits. The survey results illustrated that about 69% of respondents thought that the brick kilns were the vital source of air pollution in the areas. The study revealed that the criteria air pollutants (CO, SO_2, NO_x, PM 2.5, PM 10, SPM) except CO exceeded the National Ambient Air Quality Standard (NAAQS) limits. The higher level of lead (Pb) and chromium (Cr) in the fly ash samples might have influenced the heavy metals pollution in the farm soil and surface water. About 100% of surface water samples exceeded the permissible standard limit for Pb. The noise level was found higher than the acceptable level (75 dB) of the Department of Environment, Bangladesh (DoE, BD) standard. Thus, the study observed that the brick kilns cause a threat to the environment and human health in the study areas.

Keywords: Brick kiln, environment, impact, pollution, toxic, Bangladesh.

1. Introduction

The industries discharged or emitted several toxic elements including, salinity, organic load (chemical oxygen demand, biological oxygen demand), inorganic matter, dissolved, suspended solids, heavy metals, and other salt residues to the environment caused severe environmental pollution (Manjushree et al., 2013). Industrial wastewater contains heavy metals that degraded the aquatic ecosystem, as well as aquatic life. Surface water in Bangladesh has been contaminated with heavy metals, causing a significant health hazard for humans (Helal et al., 2011). The brick kilns are blamed for adding environmental pollution in different parts of Asia including, Bangladesh, India, and Sri Lanka. The number of brick kilns in Bangladesh is likely to exceed 10,000 (BUET, 2007). The annual rate of demand for the bricks is rapidly increasing every year for profligate industrialization. Industrialization in Bangladesh is growing without any proper planning and management. The brick-making sector is the largest buyers of coal as brick burning is an energy-intensive process (around 24 million tons/year) in Bangladesh. It is also the source of the largest air pollutants (World Bank, 2011). The brick kiln emissions the trends in air quality over the past decade stated that seasonal variations in both the PM 2.5 and PM 10 concentrations occurred and exceeded the national standards during the dry season while they were below the standards during the rainy season (Islam and Afrin, 2015). The hazardous elements are presently brought forward from the brick kilns every year. The elements mixed up with air, soil, and water resulting in changes of physical, chemical, and biological properties, and it causes environmental pollution. Most of the brick kilns have not well designed with enough ventilation facilities that resulted in incompetent fuel-air mixing and incomplete combustion of fuel (Maithel et al., 2012). It produces blackish smoke containing harmful gases and short-lived climate pollutants (SLCPs) such as black carbon. The emission of CO_2 and SLCPs from the traditional brick kilns impact on the meteorological conditions of South Asia (CCAC, 2014). It also contributes to regional and global warming (Skinder et al., 2014). Brick kilns smoke and haze engulfed is a regular phenomenon in South Asia. Islam (2002) stated that half a dozen brick-manufacturing factories spewing out brown smoky haze at Gaffargaon Upazilla of Mymensingh district in Bangladesh. Another study reported that the brick kilns smoke and haze are engulfed every morning and evening in the Panchkhal Valley of Kavrepalanchowk district in Nepal (Bam, 2018). Brick manufacturing in Bangladesh and among the top three sectors, along with vehicle exhaust and suspended road dust, contributing to the air pollution and health problems in Dhaka. A research report illustrated that a total of released gases and particulate matters from the brick kilns in the Dhaka region of Bangladesh were estimated to be 15,500 tons of SO_2, 302,000 tons of CO, 23,300 tons of PM 2.5, 6,000 tons of BC, and 1.8 million tons of CO_2 emissions. It produced severe air pollution in the region (Guttikunda et al., 2013). The brick kilns have both long-term and short-term impacts in the agricultural sector including, vegetation hampers, loss of crop yield, plant fruits fall, etc. It also impacted ozone depletion, global warming, photochemical smog's, land fertility decreases, etc. (Pokhrel

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and Lee, 2011). Moreover, the brick kilns are considered to be vital for environmental contamination of surrounding areas. Dey and Dey (2015) analyzed the various physicochemical properties of like WT, pH, EC, Transparency, TA, DO, FCO_2, nitrate, and phosphate to study the impact of brick industries of Cachar district, Assam on the aquatic bodies by using Standard Methods. They found that the water temperature (WT) in the aquatic system near the brick kilns increased due to the emissions of heat from the kilns, which slightly raise the water temperature in nearby aquatic systems. Morley (2012) reported that each kiln burned an average of 350 tons of woods per year, and the number of kilns is increasing every year resulted in devastating effects on the forests. A survey conducted on the brick kiln areas and stated that inhabitant near the kilns is more likely to suffer from health hazards caused by pollution of kilns, comparing those who are not living in the areas of the brick kilns (Joshi and Dudani, 2008). The brick-making sector in Bangladesh relies on the manual labor of millions of workers. Ghoshal (2008) conducted a study in Tripura of Indian that illustrated the working and living conditions of the brick kiln workers were not satisfactory. The Government of Bangladesh amended the Brick Kiln Control Act (2001) that prohibits the setup of the brick kilns within a three-kilometer radius of human inhabitation as well as an orchard. However, with the lack of administrative manpower and infrastructure facilities, the act remains a useless one, as the kilns are even operating less than one kilometer of a densely colonized area (DoE, 2013). The adverse effects on the physical and chemical properties of the ambient air, surface water, farm soil, sound quality, crop production, and human communities affected by the brick kilns emissions are now a matter of great concern. The study aimed to assess the impacts of brick kilns on the environment around the kiln areas of Bangladesh.

2. Materials and Methods

The study consisted of two parts, i.e., one was a questionnaire survey, and another was laboratory experiments through sample collection and analyses. The study selected twelve (12) brick kiln clusters in Rajshahi and Gazipur Districts. Rajshahi is a district in the north-western part of Bangladesh. It is lying between 24°22′26″ in north longitude and 88°36′4″ in east latitude. The climate of Rajshahi is generally marked with monsoons, high temperature, considerable humidity, and moderate rainfall. The hot season commences early in March and continues till the middle of July. The maximum mean temperature observed is about 32 to 36 °C (90 to 97°F) during April, May, June, and July. The minimum temperature recorded in January is about 7 to 16°C (45 to 61°F). The highest rainfall is observed during the months of monsoon. The average height of the Rajshahi district from the mean sea level is 18 meters. The average annual rainfall in the district is about 1,448 mm (BBS, 2013a). Another sampling location, Gazipur is a district in the central part of Bangladesh. It is lying between 24°54′5″ in north longitude and 90°24′45″ in east latitude. Gazipur has a tropical climate. The summers are much rainier than the winters in Gazipur. The average minimum and maximum temperature in Gazipur are 12.7°C and 36.0°C, respectively. The average height of the Gazipur from the mean sea level is 34 meters. The average annual rainfall is 2376 mm (BBS, 2013b).

A structured questionnaire comprised of simple and direct questions was developed by the research team using focus group discussion (FGD). Finally, it was pre-tested by the opinions of the experts and respondents. The questionnaire survey was conducted to understand public awareness of different environmental and social issues due to the brick kiln emissions. The questionnaire survey was conducted through personal interviews of the respondents of the study areas. A total of seven hundred (700) respondents took part in the survey. There were five types of samples, i.e., ambient air, farm soil, fly ash, surface water, and noise sample collected, and some instant data were recorded from different sampling locations in the study area. A total of 72 representative samples were collected during the pre-production, production, and post-production seasons over two years. The ambient air and noise were recorded only in the production season. A high volume air sampler was used (Gray Wolf Sensing, Ireland, and Casella CEL, UK) to assess the air quality around the brick kiln area. The air quality parameters, namely CO, SO_2, NO_x, PM 2.5, PM 10, SPM, O_2, CO_2, AT, RH, H_2S, C_8H_6, C_6H_6, TVOC, respectively were recorded during the ambient air sampling. The farm soil samples were collected at the depth of 0-15 cm for laboratory analysis. The fly ash samples were collected from different types of crop and tree leaves at different sampling locations. The selection of the surface water body for the collection of water samples was based on nearness to brick kiln areas as the study comprised determination of contamination in water. Several physicochemical parameters, including temperature, pH, EC, DO, TDS, TSS, BOD_5, COD, NH_3, TC, FC, salinity, turbidity, heavy metals, and anions were considered for analysis of the farm soil, fly ash and water. A precision noise level meter (Lutron, SL-410, Taiwan) was used to detect the noise intensity of different sources. The samples were analyzed using different conventional and standard scientific methods. The results were then analyzed using various computer soft wares like MS Office, Arc GIS, Adobe Photoshop, etc., after QA/QC of the data and the analysis techniques and results obtained. The analysis data were compared with national and international standards.

2.1. 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 method Hakanson, 1980. The computing equation for contamination factor (C^i_f) and the degree of contamination (C_d) are as follows:

$$C^i_f = \frac{C_i}{C^i_n} \quad \text{.......} \quad (1)$$

$$C_d = \sum_{i=1}^{n} C^i_f \quad \text{.......} \quad (2)$$

Where C^i is the measured concentration of the heavy metals in farm soil.

2.1.1. 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:

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

Where n is the number of metals (n = 5 in this study) and C_f is the contamination factor.

2.1.2. 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:

$$E^i_r = T^i_r \times C^i_f \quad (4)$$

$$RI = \sum_{i=1}^{n} E^i_r \quad (5)$$

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.

3. Results and Discussion

The study determined the impacts of the brick kiln emissions around the kiln areas. The results obtained from the field survey and sampling analyses of different types of samples are incorporated in this study. The results are interpreted and discussed in the following sections.

3.1. Survey Responses

During the study, several respondents have given their opinions regarding the brick kiln impacts on environmental degradation, crop yield, soil and land condition, deforestation, occupational situation, etc. The responses to the survey questionnaire are discussed below.

3.1.1. Environmental Degradation

The respondents in the study area were assumed to face several environmental degradation issues surrounding the brick kiln areas. The study considered several assessment parameters to measure their extent of vulnerability (Table 1). The peoples' perception regarding various environmental degradation illustrated that about 69 and 68% of highly vulnerable to air pollution and hamper natural environment, respectively, due to brick kilns (Table 1). However, about 64% of the population did not make any comments on noise pollution due to brick kilns. The results indicated that most of the people thought that the brick kilns were high to medium level of vulnerable to different environmental degradation parameters. The vulnerability assessment results indicated that the selected parameters have significant influences on the environment in the brick kiln areas. Guttikunda and Khaliquzzaman (2014) reported that the brick kilns in agricultural lands, low quality wooden fuel in the brick kiln, improperly fixed chimneys, and the violation of laws to conserve the environment is leading this sector into a major cause of environmental pollution. Moreover, the study observed that there was almost no monitoring and controlling of the brick kiln operation process due to the lack of administrative and logistical supports towards improving environmental sustainability.

Table 1. Survey responses to vulnerability level on environmental degradation.

Assessment parameters	Assessment on vulnerability level			No comments (%)
	High (%)	Medium (%)	Low (%)	
Hamper the natural environment	67.86	17.14	9.28	5.72
Air pollution	69.28	19.29	5.00	6.43
Water pollution	27.86	25.00	12.86	34.28
Soil pollution	35.71	22.86	20.00	21.43
Noise pollution	9.29	16.43	10.00	64.28
Raising ambient temperature	46.43	24.99	17.86	10.72
Affected biodiversity	32.15	28.57	3.57	35.71
Overall assessment	44.23	22.04	11.23	25.51

3.1.2. Socio-Environmental Issues

There are some socio-environmental issues raised in the brick kiln areas. These issues were loss of crop production, land and soil degradation, solid waste generation, disrupted transportation system, deforestation, hampers labor rights, complexity in a social relationship, etc. The field survey responses to socio-environmental issues relevant to the brick kilns are summarized in Table 2. The survey result revealed that the farmers near the brick kilns got less food production due to brick kiln emissions. All types of agricultural plants near the kiln areas were in an exhausted condition. The temperature rise and emission gases from brick kilns have caused severe impacts on the fruit plants in Rajshahi areas. The diseases include mango splatter and damage in mango stalk, growth affected in jackfruits, root damage in banana, spotted leaves and production loss in litchi, sacking the vegetation, and finally expire in date palms and immaturity and spotted surface in green coconut. It also observed that the mango production near the brick kilns was hampered due to the increase in ambient temperature. The study results showed that about 65% of brick kilns were situated in agricultural land. The farm soil is used as a vital raw material for brick production, and about 95% of the brick-making soils were collected from the topsoil of the agricultural lands, so every year, the agricultural lands lose fertility. Besides, agricultural lands also lose by installing new brick kilns. Nusrat and Mahadev (1991) investigated the loss of soil fertility due to brick making soil in Mysore in India. The study also observed that the brick kiln created about 50 and 55% of unwanted wetland and waterlogging conditions in the study areas, respectively (Table 2). Mazumdar et al. (2018) reported that water logging is a serious problem around the brick kiln areas. The survey results showed that the brick kiln produced different types of solid waste, such as broken parts of bricks, coal, and wood, etc. The coal ash and wooden trash also the source of solid waste in the brick kilns. Moreover, over burnt and broken bricks also produced a substantial amount of waste. This excess amount of wastes gets dispersed to neighboring areas by blowing wind or by human activities. A study conducted by Das (2015) on brick kilns and stated that the several negative impacts of brick kiln identified, solid waste generation is one of them at Khejuri blocks, Medinipur, West Bengal in India.

The study apparent that essential brick burning fuel used as forest wood, and about 40% used fuel as wood in the study areas. The brick kiln has a high impact on the deforestation process. The consumption of biomass fuels is generally considered to be neutral to emissions of carbonaceous greenhouse gases, which means the CO_2 emitted during the brick burning process. Morley (2012) reported that each brick kiln burned 350 tons of woods a year in Bangladesh, so more kilns mean having a devastating effect on the forests. The other parameters, such as disrupted transportation system, visibility reduction, Complexity in a social relationship, etc. have impacts on socio-environmental deprivation. Das (2015) conducted research on land degradation by brick kin setup stated that different types of socio-economic and environmental problems raised due to brick kiln at Khejuri blocks, PurbaMedinipur, West Bengal in India. Therefore, the brick kiln act as a genuine agent of land and soil degradation, deforestation, etc. and as well as environmental degradation.

Table 2. Field responses to socio-environmental issues.

Socio-environmental issue	Effect	Percentage (%) of loss
Loss of crop production	Crop disease	25% crops
	Low production	15% crops
Land and soil degradation	Agricultural land loss	65% brick kiln situated in ag. land
	Removal of topsoil	95% collected soil from ag. land
	Formation wet land	50% brick kiln areas
Threat for irrigation and water management	Water logging condition	55% brick kiln areas
	Damage command area	15% brick kiln areas
Solid waste generation	Affected areas	35% surrounding areas
Disrupted transportation system	Town road	15% damage
	Village road	35% damage
Degraded river condition	River grabbing	15% sampling locations
	River pollution	10% sampling locations
Deforestation	Brick kiln setup	30% brick kiln areas
	Fuel wood	40% used fuel
Visibility reduction	Smog formation	40% brick kiln areas
Hamper labors right	Physically damaged	35% labors injured
	Poor accommodation	Almost 100% kiln areas
	Child labor	15% labor were child
Complexity in social relationship	Conflict between kiln owner and community people	Almost 100% kiln areas

3.2 Ambient Air Pollution

The brick kiln in Bangladesh is highly energy-intensive and carbon-emitting. It includes land clearing for sand and clay, combustion of fuel for burning, uses of diesel engines on-site, and finally, transportation of the end product that's led to cause air pollution. The study results of ambient air quality showed that most of the parameters exceeded the permissible standard limit. The biomass fuels like firewood, coal and diesel were responsible for emitting particulates and toxic gasses such as SO_2, NO_x, and CO_2 in the kiln areas. The ash and sulfur-containing coals together with rubber tires are using as initial firing material for manufacturing brick has to lead to increasing enormous emissions. The heavy metal contaminations occurred in the atmosphere, aquatic bodies, and soil surface due to fossil fuels. The criteria air pollutants (CO, SO_2, NO_x, PM 2.5, PM 10, SPM) except CO exceeded the National Ambient Air Quality Standard (NAAQS) limits. Most of the parameters exceeded the NAAQS standards at all sampling locations. The particulate matter concentration in ambient air was found highest among all types of ambient air quality parameters. The concentrations of PM 2.5 and 10, and SPM were ranged from 57 to 2573, 287 to 3875, and 519 to 1950 μg/m^3, respectively (Table 3).

Guttikunda (2009) stated that brick kilns emitted PM 2.5, which considered being harmful to humans because it can travel deeper into the respiratory system and cause premature mortality and respiratory ailments. The concentration of criteria air pollutants was found higher in the Gazipur region than the Rajshahi due to the higher number of brick kilns per cluster in the areas (Figure 1). Some vital parameters of air quality monitoring, including O_2, ambient temperature (AT), relative humidity (RH), and C_6H_6 violated the permissible standard limit, which influenced the entire condition of ambient air quality. The study found that CO_2 present in the ambient air was within the limit (OSHA, 2010), but, the increase in CO_2 concentrations is known to cause smaller stomatal apertures in the plant. Hence the decrease in the leaf conductance for water vapor (Morison and Gifford, 1987). The study showed that the ambient temperature was found to be higher around the kiln areas due to kiln heat emitted during the brick production season. But the average temperature of Bangladesh ranges from 7.2 to 12.8°C during winter and 23.9 to 31.1°C during summer (Shahid, 2010).

The ambient temperature and relative humidity during the peak brick production season (January-February) were found to be higher than the areas about one Km away from a kiln indicating the kiln emitted heat has a significant influence on the environment. The gaseous pollutants, CO, H_2S, C_8H_6, and TVOC were found very low at all locations indicating not be harmful to the environment (Table 3). However, the inappropriate process of the kiln may increase emissions. Higher emissions are also expected during the stabilization period after startup in the new season. Cui et al. (2015) reported that air pollutants deposited on the ground and seeped into the soil affected the soil pH and lead to permanent degradation. Several plants are sensitive to air pollutants, as they can damage their leaves, impair plant, growth, and limit primary productivity (Ulrich, 1984). A study conducted the effects of ambient air pollutants including, NO_x, SO_2, and particulate matters on some crops grown in the urban and industrial areas of Haridwar city (Chauhan and Joshi, 2010). It observed that the gaseous (SO_2 and NO_x) and particulate pollutants have detrimental effects on the crops through changes in morphological characteristics, photosynthetic pigments, and yield of crops.

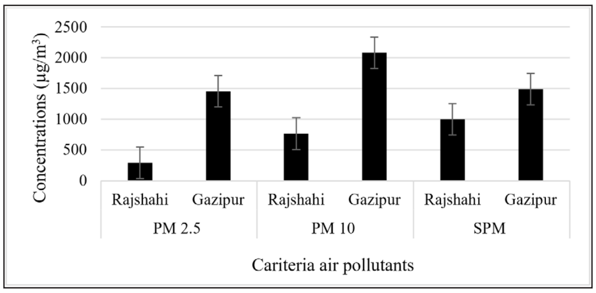

Figure 1. Biyearly concentrations of particulate criteria air pollutants during the brick production season (January-April) in 2016-2017.

Table 3. Statistical analysis of ambient air quality parameters and comparison with the standard limits.

Parameters	Study area	No. of Samples	Minimum	Maximum	Mean ± SD	No. of Sample exceed/below	Permissible standard
NO_x (ppm)	Rajshahi	16	0.008	0.222	0.075 ± 0.049	>07	0.053 ppm (AA, NAAQS, 2005)
	Gazipur	08	0.167	0.972	0.489 ± 0.327	>08	
SO_2 (ppm)	Rajshahi	16	0.039	0.423	0.148 ± 0.104	>16	0.03 ppm (AA, NAAQS, 2005)
	Gazipur	08	0.078	0.612	0.253 ± 0.181	>08	
CO (ppm)	Rajshahi	16	0.91	3.10	1.855 ± 0.626	Within the limit	35 ppm (AA, NAAQS, 2005)
	Gazipur	08	0.41	2.80	2.006 ± 0.860	Within the limit	
PM 2.5 (μg/m³)	Rajshahi	16	57	821	289.18 ± 249.07	>16	50 μg/m³ (AA, NAAQS, 2005)
	Gazipur	08	725	2573	1454.25 ± 697.75	>08	
PM 10 (μg/m³)	Rajshahi	16	287	1523	766.69 ± 315.59	>16	15 μg/m³ (AA, NAAQS, 2005)
	Gazipur	08	1134	3875	2083.25 ± 991.43	>08	
SPM (μg/m³)	Rajshahi	16	519	1653	998.69 ± 319.72	>16	140 μg/m³ (AA, NAAQS, 2005)
	Gazipur	08	1052	1950	1491 ± 408.61	>08	
O_2 (%)	Rajshahi	16	17.3	20.1	18.63 ± 0.80	16<	20.95% (IAC)
	Gazipur	08	17.7	18.5	17.85 ± 0.54	08<	
CO_2 (ppm)	Rajshahi	16	428	582	504.56 ± 38.70	Within the limit	5000 ppm (OSHA)
	Gazipur	08	415	814	651.37 ± 130.65	Within the limit	
AT (°C)	Rajshahi	16	29.80	35.00	32.54 ± 1.66	>16	25 °C (IAC)
	Gazipur	08	35.40	39.10	37.69 ± 1.29	>08	
RH (%)	Rajshahi	16	68.3	76.5	72.66 ± 2.87	>16	40-50% (IAC)
	Gazipur	08	65.0	73.5	68.85 ± 3.10	>08	
H_2S (ppm)	Rajshahi	16	0.014734	0.125239	0.059 ± 0.033	Within the limit	15 ppm (WSH Act, 2006)
	Gazipur	08	0.014734	0.176808	0.073 ± 0.054	Within the limit	
C_8H_6 (ppm)	Rajshahi	16	0.043	0.145	0.083 ± 0.031	Within the limit	50 ppm (WSH Act, 2006)
	Gazipur	08	0.0529	0.0835	0.069 ± 0.011	Within the limit	
C_6H_6 (ppm)	Rajshahi	16	0.0324	0.139	0.082 ± 0.031	>16	0.001608 ppm (AA, NAAQS, 2009)
	Gazipur	08	0.063	0.096	0.078 ± 0.010	>08	
TVOC (ppm)	Rajshahi	16	0.092	0.285	0.159 ± 0.063	-	Not set
	Gazipur	08	0.114	0.172	0.143 ± 0.020	-	

The enormity of air pollution has always been a matter of concern due to the rapid development of brick kiln over a long period. However, the pollutants including NO_x, SO_2, CO, O_2, C_6H_6, PM 2.5, PM 10, and SPM were detected at a higher level, violating the standard in ambient air in the brick kiln has deteriorated the air quality at an alarming rate.

3.3. Farm Soil Pollution

The soil is a natural resource made of mineral and organic constituents. Farm soil degradation is one of the most serious problems in the world. Three-quarters of the world soil degradation occurs in tropical areas, and about 7% of the total land area (13,391 km²) of Bangladesh is experiencing land degradation but, the soil degradation has not been considered due to brick production so far (Eswaran, 1999). The pH and organic matter in the farm soil samples were found to be very low. So the nutrient elements and soil biota of the topsoil are destroyed through brick burning. Khan et al. (2007) found that the brick burning process decreased the average pH values of soils with the depth function. It has greatly influenced the concentrations of greenhouse gases in the atmosphere. Thus, it is essential to investigate the contribution of soil to the release and fixation of greenhouse gases (IUSS, 2002). The brick kilns emitted heat seriously degraded the farm soil quality. A report showed that the brick burning emitted heat reduces the surrounding soil moisture (Mazumdar et al., 2018). The nutrients of the farm soil, which are generally found in the top layer were affected and destroyed through heat emission. The results showed that most of the organic matter content in the production season was lower compared to other seasons. The lower values of organic matter (OM) and organic carbon in the soil are responsible for the lower cation exchange capacity, holding capacity, soil erosion, and reduces microbial activity (Van Loon and Duffy, 2007). The farm soil parameters, such as pH, organic matter, soil texture were found to be critical conditions. Most of the farm soil samples found more than 50% of sand particles in the production seasons (Table 4). There are no available standards of the above parameters, and therefore some published reports' observations were cited here to evaluate the soil status. A report showed that the soil texture might be affected by wind erosion that produced dust around the brick kiln (Abuduwaili and Mu, 2002). 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, 2004).

Table 4. Statistical analysis of farm soil parameters comparison with the standards.

Parameters	Study area	No. of Samples	Minimum	Maximum	Mean ± SD	Sample exceed / below (No.)	Reference of permissible standard
pH	Rajshahi	48	6.18	8.29	7.67 ± 0.46	>12/<1	6.5 - 8.0 Tisdale et al. (1999)
	Gazipur	24	6.60	8.48	7.44 ± 0.50	>4	
OM (%)	Rajshahi	48	0.58	3.21	1.51 ± 0.49	<20	> 1.38 % Neupane and Bishat (2015)
	Gazipur	24	0.34	1.47	0.93 ± 0.32	<22	
Soil texture	Rajshahi	48	Sample content > 50 % of sand particles		56.29%	>34	Hannan (1995)
	Gazipur	24			64.97%	>18	
Pb (ppm)	Rajshahi	48	9.53	31.27	16.66 ± 5.81	On limit	300.00 ppm (DEP, 2003)
	Gazipur	24	6.54	23.86	11.53 ± 5.09	On limit	
Cr (ppm)	Rajshahi	48	9.50	52.77	26.77 ± 12.22	>02	50.00 ppm (DEP, 2003)
	Gazipur	24	16.54	70.13	37.61 ± 13.94	>04	
Cd (ppm)	Rajshahi	48	0.42	1.95	0.97 ± 0.32	On limit	3.00 ppm (DEP, 2003)
	Gazipur	24	0.91	1.85	1.19 ± 0.24	On limit	
As (ppm)	Rajshahi	48	2.90	6.80	5.01 ± 0.91	On limit	20.00 ppm (DEP, 2003)
	Gazipur	24	1.10	3.40	2.02 ± 0.53	On limit	
Fe (ppm)	Rajshahi	48	1.12	3.03	2.02 ± 0.47	<48	20000 – 550000 ppm Bodek et al. (1988)
	Gazipur	24	1.59	2.81	2.16 ± 0.34	<24	
Zn (ppm)	Rajshahi	48	12.68	79.34	41.23 ± 18.21	>45	16.00 ppm Crommentuijn et al. (1997)
	Gazipur	24	11.24	78.51	40.58 ± 20.41	>20	

The brick kilns are one of the principal causes of topsoil degradation and environmental pollution. They degraded large areas of land every year, especially in Bangladesh. The brick-making soils collected from a depth of about 1 to 2 m of agricultural land. The land areas extended over about 5000 ha during the year 1998-99 in different pockets of brickfields (Rahman and Khan, 2001). The heavy metals, like Pb, Cd, and As were found to be very low at all of the farm soils indicated not harmful to the agricultural work (Table 4). The Cr, Fe, and Zn ion violated the permissible standard limits of soil samples among the heavy metals. The concentration of heavy metals, including Cr, Fe, and Zn ion varied from 9.50 to 70.13, 1.12 to 3.03, and 11.24 to 79.34 ppm in the study area, respectively (Table 4). The higher concentration of the toxic metal ions in the soils with the acidic pH affected the plants. Kudesia (1990) stated that brick kiln used low-quality coal seems to have high Cr concentration may also be the cause of plant growth reduction, soil fertility loss, and also, some hazardous diseases of the human being. The concentration of heavy metals at different locations varies might be attributed to the direction and velocity of wind, age of the topsoil, deposition of heavy metals, etc. The study observed that most of the heavy metal concentration in the farm soils of the Gazipur region is higher than the Rajshahi region (Figure 2). The results indicated that the maximum concentration of metal ions found in Gazipur may be due to the higher number of kilns per cluster in Gazipur districts compared to Rajshahi. Budhwar et al. (2006) studied the effect of brick kiln emitted heavy metals on the soil and plants around the brick kiln chimneys. The results showed that only Cr exceeded the permissible standard limit of some soil samples. 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 threat to human health, who consumed the contaminated crops (Ochieng et al., 2010).

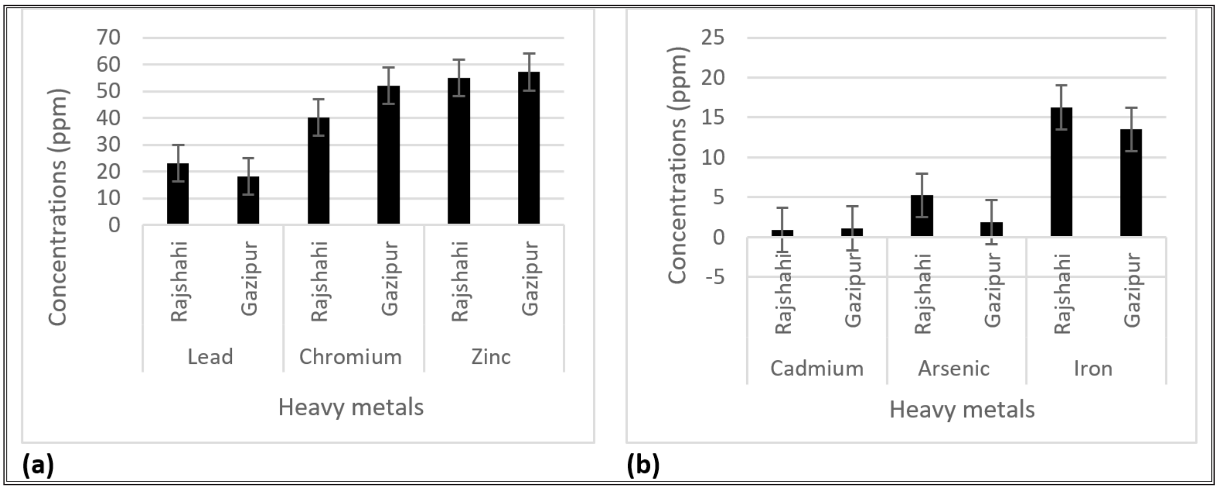

Figure 2. Biyearly concentrations of heavy metals in farm soil samples during the production season (January-April) in 2016-2017.

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 (Table 5). The study results showed that pollution load index and risk index values were found lower than 1 and 150, respectively, at all sampling locations indicating low risk and pollution from heavy metals in the areas (Table 5). A study conducted on the impacts of industrial effluents on the soil in BSCIC of Rajshahi revealed that the heavy metals contamination in the industrial areas showed a lower pollution load index and low-risk index. The observation supports the present finding (Hossain, 2018). However, the continuation of brick kilns operation in the areas would become threatened for soil fertility in the future.

The fly ash is a byproduct of a brick kiln disposed of in the form of ash slurry into the surrounding land, waterbody, vegetation, etc. Heavy metal contamination in the environment is a global problem that is a growing threat to human beings. The study conducted to estimate the content of heavy metal in the fly ash produced from the brick kiln. There is no standard permissible limit available for heavy metals in the fly ash. It contains an appreciable amount of Pb, Cr, and Cd (USEPA, 2003). The study observed that firewood, coal, and petroleum were used as fuel for brick burning, which produced fly ash enriched with heavy metals including Pb and Cr in the production seasons at the kiln areas. Al-Hiyaly et al. (1988) reported that the fly ash produced from coal burning, which added a higher concentration of Pb into the environment. 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 (Table 6).

The study findings supported the report of Verma et al. (2017), which showed a higher concentration of heavy metals in the production season compared to other seasons. The heavy metals concentration of collected fly ash samples in the areas followed in the order: production season> post-production season > pre-production season (not shown in Table). The study results revealed that the fly ash produced from the combustion process of brick kilns is one of the sources of heavy metal pollution. The fly ash and surface run-off contaminated water from the kilns areas indisputably declines the soil fertility and crop production in the surrounding agricultural lands. The presence of heavy metals in the fly ash is a matter of concern. Moreover, the disposal of such huge amounts of fly ash degraded the entire environment.

Table 5. Biyearly of contamination factors (C^i_f), pollution load index (PLI), potential ecological risk factors (E^i_r) and risk index (RI) of heavy metals in farm soil samples during September 2015 - August 2017.

Study area	Contamination factors (C^i_f)					Pollution load index (*PLI*)	Potential ecological risk factors (E^i_r)					Risk index (*RI*)
	Pb	Cr	Cd	As	Zn		Pb	Cr	Cd	As	Zn	
Rajshahi	0.239	0.297	0.976	0.334	0.235	0.303	1.189	0.594	29.253	3.341	0.235	34.616
Gazipur	0.167	0.417	1.189	0.135	0.232	0.291	1.081	0.668	31.24	2.728	0.234	35.943

Table 6. Biyearly descriptive statistics ofheavy metal concentration in fly ash samples from September 2015 - August 2017.

Heavy metals	Study area	Minimum	Maximum	Mean ± SD
Lead (Pb)	Rajshahi	1.9862	26.2878	9.59 ± 7.96
	Gazipur	3.0458	24.8154	11.01 ± 7.83
Chromium (Cr)	Rajshahi	0.8517	18.2155	9.26 ± 5.90
	Gazipur	3.2065	19.2111	12.35 ± 5.70
Cadmium (Cd)	Rajshahi	0.0098	0.0934	0.032 ± 0.019
	Gazipur	0.0063	0.0643	0.026 ± 0.014
Arsenic (As)	Rajshahi	0.0001	0.0074	0.003 ± 0.002
	Gazipur	0.0005	0.0096	0.003 ± 0.002
Iron (Fe)	Rajshahi	0.0048	0.0640	0.020 ± 0.012
	Gazipur	0.0094	0.0738	0.032 ± 0.022
Zinc (Zn)	Rajshahi	0.0023	0.0917	0.041 ± 0.022
	Gazipur	0.0026	0.1124	0.040 ± 0.029

3.4 Surface Water Pollution

The surface water reflects its ecological potential and sustenance quality by its biological, chemical, and physical characteristics. The study analyzed the concentration of different parameters in aquatic bodies near the brick kilns. The DO concentration in most of the surface water samples was found lower, and the lowest concentration of DO was 1.0 mg/l found in the Gazipur area (not shown in Table). The study observed that the DO values of most of the surface water samples were found lower compared to the standard limit in both the study areas indicating surface water was not suitable for aquatic life. Cox (2003) reported that aquatic animals are forced to alter their breathing patterns or lower their level of activities in a reduced DO level in a water body. The study also revealed that very few numbers of samples exceeded the permissible standards limit in Gazipur, and the water was more turbid in affected water bodies. The biyearly mean value of turbidity in the collected surface water samples was 24.24 and 33.89 NTU in Rajshahi and Gazipur, respectively (Table 7). The turbidity variation in the surface water at different locations might be due to the pollution loads in the water. Mazumdar et al. (2018) reported that the high turbidity might be responsible for the high level of water temperature in the water bodies near brick kiln because the suspended particles absorb the heat from the sunlight making the water warm. The biyearly mean value of color in the collected surface water samples was 42.29 and 63.75 pt-co in Rajshahi and Gazipur, respectively (Table 7). The higher color concentration of water might be due to the presence of oxygen demanding wastes, dissolved solids, and particulate materials in the surface water. During brick production, huge amounts of particulates, including fly ashes and suspended particles, and finally, it fell into the surface water bodies. The study observed that the degree of color in the surface water increased every year and the rate of increasing the trend indicating declined the surface water quality. Saha et al. (2020a; 2020b) reported that oxygen depletion occurs by the pollutants affecting the taste, odors, and colors in surface water and also affects aquatic life.

Table 7. Statistical analysis s of physicochemical parameters of surface water and comparison with the standard limits.

Parameters	Study area	No. of Samples	Minimum	Maximum	Mean ± SD	Violation of No. of Samples	Permissible standard
pH	Rajshahi	48	5.15	7.64	6.72 ± 0.54	<5	6 – 9 (DoE, 2003)
	Gazipur	24	6.09	7.65	6.72 ± 0.44	0	
DO (mg/l)	Rajshahi	48	2.5	6.2	4.19 ± 0.92	<27	4.5 – 8.0 mg/l (DoE, 2003)
	Gazipur	24	1.0	4.9	2.70 ± 1.16	<23	
Turbidity (NTU)	Rajshahi	48	9	41.4	24.24 ± 8.83	0	1 - 50 NTU (USGS, 2006)
	Gazipur	24	11.0	55.1	33.89 ± 12.41	>3	
Color (pt – co)	Rajshahi	48	7	88	42.29 ± 22.29	>44	15 pt – co (WHO, 2003)
	Gazipur	24	32	97	63.75 ± 18.92	>24	
(mg/l)	Rajshahi	48	5.9	65.3	26.20 ± 18.73	>39	10 mg/l (DoE, 2003)
	Gazipur	24	7.0	68.4	30.71 ± 23.11	>21	
(mg/l)	Rajshahi	48	2.7	24.1	8.28 ± 5.17	16	10 mg/l (ECR, 1997)
	Gazipur	24	2.6	13.0	6.83 ± 3.28	>4	
F^- (mg/l)	Rajshahi	48	0.14	2.15	0.79 ± 0.57	>3	2 mg/l (ECR, 1997)
	Gazipur	24	0.23	1.89	0.89 ± 0.60	0	
Pb (ppm)	Rajshahi	48	0.1239	4.9528	2.32 ± 1.23	>48	0.10 ppm (DoE, 2003)
	Gazipur	24	0.7234	4.8152	2.09 ± 1.27	>24	
Cr (ppm)	Rajshahi	48	0.0015	3.9338	1.44 ± 1.18	>32	0.50 ppm (DoE, 2003)
	Gazipur	24	0.0294	3.1217	1.40 ± 1.20	>17	
Cd (ppm)	Rajshahi	48	0.009	0.018	0.040 ± 0.020	>8	0.05 ppm (DoE, 2003)
	Gazipur	24	0.095	0.0048	0.040 ± 0.026	>6	
Fe (ppm)	Rajshahi	48	0.154	0.512	0.316 ± 0.080	0	2.00 ppm (DoE, 2003)
	Gazipur	24	1.850	3.012	2.36 ± 0.354	>21	
FC (CFU/100 ml)	Rajshahi	48	26	95	48.06 ± 16.79	>48	0 CFU/100 ml (WHO, 2003)
	Gazipur	24	21	54	33.16 ± 8.51	>24	
TC (CFU/100 ml)	Rajshahi	48	<100	>200	>150	>48	0 CFU/100 ml (WHO, 2003)
	Gazipur	24	<100	>200	>150	>24	

Among the anionic parameters of the surface water, (NO_3^-), nitrite (NO_2^-), and fluoride (F^-) ions exceeded the standard limits. The (NO_3^-) and, nitrite (NO_2^-) ion concentrations in surface water exceeded the permissible limit at both the study areas indicating significantly harmful to humans, flora, and fauna (Table 7). Kacaroglu and Gunay (1997) reported that the presence of nitrate concentration was higher than 5 mg/l reflecting unsanitary conditions. So it may be called, due to combustion residue of the brick kiln and its blown fly ash and removal of the topsoil layer from the agricultural land, ultimately the eroded soil goes to the nearby aquatic system through catchment channels.

The concentrations of anions, including nitrate, nitrite, and fluoride ions were varied from 5.9 to 68.4, 2.7 to 24.1, and 0.14 to 2.15 mg/l, respectively (Table 7). Vandeviver et al. (1998) reported that the higher concentration of nitrite was highly toxic to humans, flora, and fauna. The result showed that a high concentration of anionic parameters might be due to the higher input load of pollutants like coal burned fly ash and different organic and inorganic pollutant in the aquatic bodies. The study observed that except for nitrite concentration, the other anions in surface water were found higher in the concentration level in the Gazipur region than the Rajshahi region due to the lower number of kilns per cluster (Figure 3). The results indicated that the maximum value of nitrite ions was found to be at Horian in Rajshahi. It may be due to the decomposed bagasse and sludge of Rajshahi sugar mills, Horian, which is very near to the sampling site. The Pb, Cr, and Fe concentrations in most of the surface water samples exceeded the permissible standard. The results illustrated that the heavy metals, including Pb, Cr, Cd, and Fe were in the range from 0.1239 to 4.9528, 0.0015 to 3.9338, 0.009 to 0.095, and 0.154 to 3.012 ppm, respectively (Table 7). Järup (2003) reported that the symptoms of acute lead poisoning are headache, irritability, abdominal pain, and various symptoms related to the nervous system. The concentrations of heavy metals in surface water at different locations were varied might be due to the fallout of pollutants in the aquatic bodies. Other studies reported that the presence of heavy metals in excessive amounts in soil, water, and air leads to several health problems including neurotoxicity, kidney toxicity, sterility, anemia, etc. (Islam and Mostafa, 2020). Al-Hiyaly et al. (1988) stated that fly ash was a vital source of ambient air pollution during the production period. It produced due to coal burning, which added a higher concentration of heavy metals like Pb into the environment. The study observed that the concentration of heavy metals like Pb, Cr, and Fe was found higher in the Gazipur region than the Rajshahi region, Fe concentration, in particular (Figure 4a).

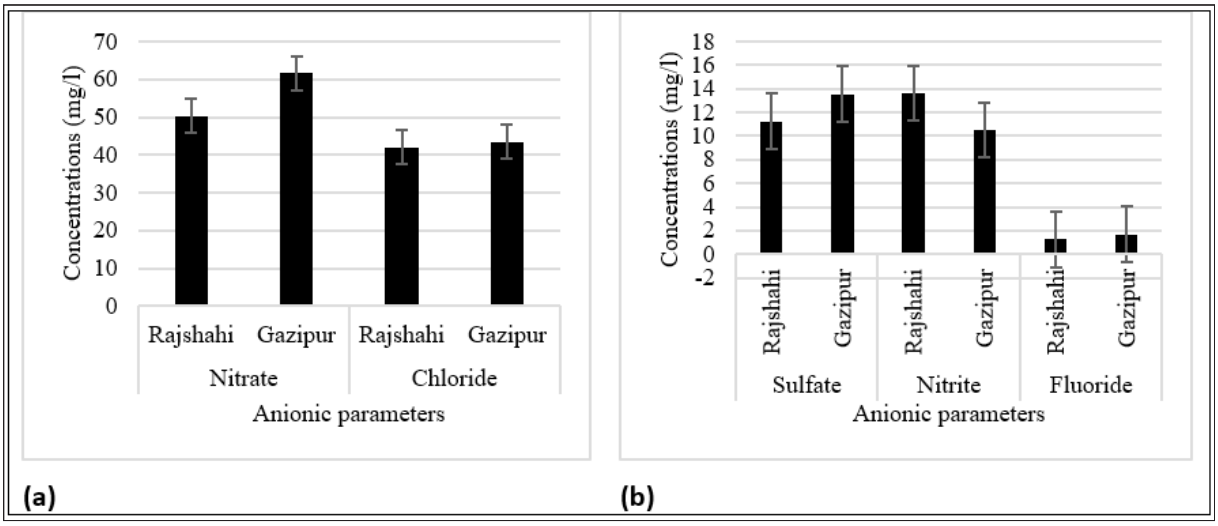

Figure 3. Biyearly concentrations of anionic parameters in surface water samples during the production season (January-April) in 2016-2017.

The results indicated that the higher numbers of brick kilns per cluster in the Gazipur than the Rajshahi areas emitted large amounts of fly ashes and other particles that might increase the heavy metals concentration of the surface water samples. The results showed that the maximum concentration of Fe found at all locations in Gazipur may be due to the presence of many wrought re-rolling mills in Gazipur districts. However, the concentration of heavy metals like Cd, As, and Zn was found lower in surface water of the Gazipur region than the Rajshahi region as the soils of the area contained these metals comparatively higher (Figure 4b). The concentrations of these heavy metals were found higher than usual concentration indicated the surface water contaminated with heavy metals. The study observed that both anions and cations were found higher concentrations in the brick production season (not shown in Table).

The other indicators of surface water, such as TC and FC values exceeded the permissible standard at all sampling locations. The TC and FC concentrations in all surface water samples exceeded the WHO's standard (0 CFU/100 ml) that may harm aquatic life and human health (Table 7). Lango et al. (2012) reported that an increased amount of bacterial population in aquatic ecosystems affected public health.

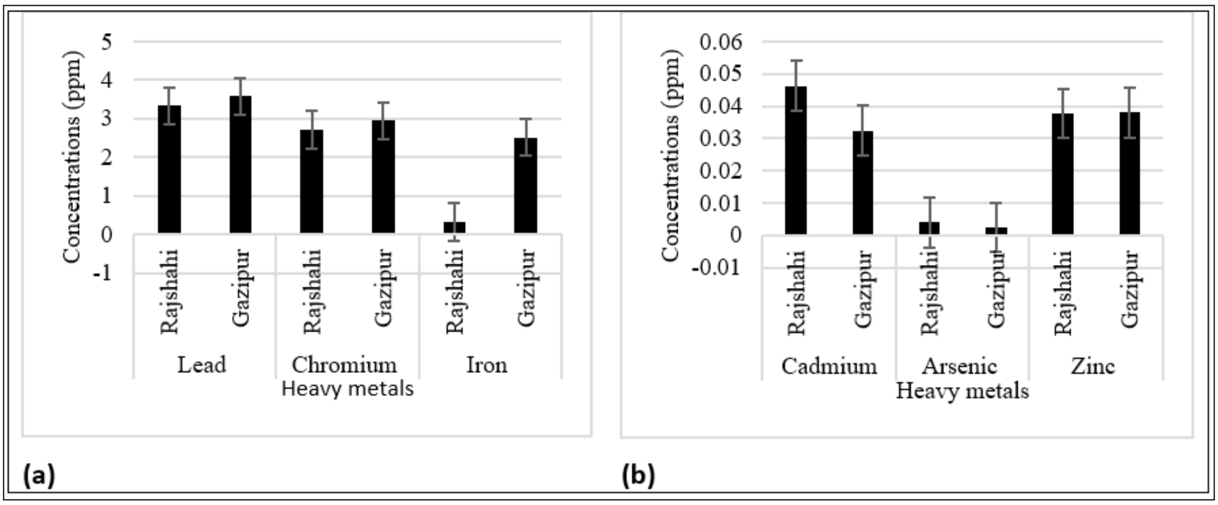

Figure 4. Biyearly concentrations of heavy metals in surface water samples during the production season (January-April) in 2016-2017.

The results indicated that the anions and cations were increased during the brick production season. It is impossible to control the dissolution of undesirable constituents in the waters once they enter into the ground (Mostafa et al., 2017; Sastri, 1994). These heavy metals in the surface water may be susceptible to severe health problems. Finally, these toxic metal ions and organometallic compounds are consumed by humans through water and foodstuffs.

3.5 Noise Pollution

The increased brick kiln activities use excessive machinery have led to several environmental problems in the study area. Jamatia et al. (2014) reported that the increase of brick kiln coupled with the haphazard manufactural set-up in a small area has resulted in a significant contribution to pollution load in the environment. A total of 24 sound sampling was done, and the noise levels were recorded during peak working hours (09:30 AM – 04:30 PM) at the kiln areas. The results showed that the average values of the noise levels were recorded to be 89.45 and 82.63 dB in Gazipur and Rajshahi, respectively (Table 8). The noise level of all the individual sources exceeded the permissible standard limit (75 dB) of noise in an industrial area (ECR, 1997). This noise level was alarming for kiln workers (Saha et al., 2019). High levels of occupational noise remain a problem in all regions of the world. NIOSH (1998) reported that 30 million and 4-5 million workers are exposed to hazardous noise in the USA and Germany, respectively. According to the World Health Organization (WHO), generally, 60 dB sounds can make deaf temporarily, and 100 dB sounds can cause complete deafness (WHO, 2002). However, the noise affects human beings physically and psychotically. The noise environment may cause hypertension, headache, sleeplessness, etc. The study observed that the machinery used in the brick kilns created a higher intensity of noise, and it has had harmful effects on human health and the environment. Eventually, the high levels of occupational noise are alarming for kiln workers.

Table 8. Average noiselevel during peak working hours.

Study Area	Sampling locations	No. of Samplings	Noise Level (dB)		
			Minimum	Maximum	Mean ± SD
Rajshahi	8	16	72.8	91.7	82.63 ± 6.51
Gazipur	4	8	80.4	94.8	89.45 ± 4.95

4. Conclusions

The survey results showed that about 69% of respondents blamed the brick kilns for the cause of air pollution in the areas. The survey study identified several impacts, including loss of crop production, river grabbing, deforestation, etc. The study revealed that the criteria air pollutants (CO, SO_2, NO_x, PM 2.5, PM 10, SPM) except CO exceeded the National Ambient Air Quality Standard (NAAQS) limits. The particulate matter concentration in ambient air was found the highest among all types of ambient air quality parameters. The particulate matters, including PM 2.5 and 10, and SPM were in the range from 57 to 2573, 287 to 3875, and 519 to 1950 μg/m^3, respectively. The brick kilns cluster emitted enormous amounts of gases in the surrounding areas would cause adverse effects on human health. The soil analysis results found that most of the farm soil samples contained more than 50% of sand particles during the production season. The pH and organic matter content in the collective farm soil samples were showed to be very low. The presence of a higher level of lead (Pb) and chromium (Cr) in the fly ash samples might have influenced the heavy metals pollution in the farm soil and surface water. About 100% of surface water samples exceeded the permissible standard limit for Pb. The fly ash and surface run-off contaminated water from the kilns areas indisputably declines the soil fertility and crop production in the surrounding agricultural lands. The study observed that the machinery used in the brick kilns created a higher intensity of noise that caused exceedances in the sound to the acceptable level in any industrial region (75 dB) of the DoE standard. Eventually, the high levels of occupational noise are alarming for kiln workers. Finally, it may be concluded that the ambient air, farm soil, and surface water around the brick kiln areas were affected in the study areas, and the contamination process will continue in the future until any remedial measures have been introduced.

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