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Environmental Degradation through Brick Kilns: An Investigation into Soil Pollution in Bangladesh

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Abstract

Brick kilns pollute worldwide soil, especially in developing nations using antiquated technology. This study reviewed existing literature to observe how brick kilns promote soil pollution and impact human health in Bangladesh. Bangladesh, the world's fourth-largest brick producer, is currently facing severe soil pollution due to many reasons, among them brick kiln is one of the main contributors. This review paper brings together findings from multiple studies, primarily in areas surrounding Dhaka, to evaluate the severity of soil pollution and the detrimental effects caused by Bangladesh's brick kilns. Despite being a significant industry, brick production degrades vast fertile agricultural land by stripping away topsoil. Continuous emissions of brick dust, fly ash, and heat also adversely modify the physical and chemical properties of surrounding soils. Studies reveal alarming concentrations of heavy metals like Lead (Pb), Chromium (Cr), Cadmium (Cd), and Zinc (Zn) in soils often exceeding acceptable safe limits in certain sampling locations. Though concentrations decrease with increasing distance, pollutants remain considerably elevated even 100-200m away. The presence of these toxic metals reduces essential nutrients, increases soil acidity and salinity, and severely impacts soil organisms by degrading fertility and quality. While existing research has highlighted the significant contribution of brick kilns to air pollution in Bangladesh, particularly in the Dhaka region, there appears to be a lack of detailed research across the country's other major cities. The gap in research across Bangladesh's other major cities exhibits the need for a more thorough, countrywide study into the effects of the rapidly growing brick kiln industry on the pollution of the environment. The paper underscores the urgency of implementing cleaner production technologies and stronger environmental regulations to mitigate further soil degradation across Bangladesh.

Keywords: brick kiln, soil pollutants, human health, soil quality of Bangladesh, heavy metals

1. Introduction

Brick kilns are a significant source of environmental pollution, particularly in developing countries where they are often operated using outdated and inefficient technologies. Brick kilns are a major factor contributing to topsoil degradation and environmental pollution, particularly in Bangladesh, where they annually degrade huge amount of land area. The soil used for brick-making is typically collected from agricultural land at depths ranging from 1 to 2 meters [1]. Soil pollution results in decreased soil productivity due to the presence of pollutants that negatively impact its physical, chemical, and biological properties [2]. Over the years, the activity of brick kilns not only blankets nearby vegetation areas with brick dust but also continuously emits heat in all directions. This process modifies the physical and chemical characteristics of the nearby soil and its living environments by reducing essential nutrient elements in the topsoil, including macronutrients like carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur, as well as micronutrients such as boron, copper, iron, manganese, molybdenum, and zinc. Additionally, it adversely affects soil organisms and their habitats [3]. Brick kilns in various parts of Asia, such as Bangladesh, India, and Sri Lanka, are accused of contributing to environmental pollution [1]. Due to a scarcity of natural stone aggregate, there is a strong demand for clay-fired bricks as a building material in Bangladesh [4]. According to the Bangladesh Brick Manufacturing Owners Association, the country's brick kilns consume more than 1.27 billion cubic feet of topsoil annually [5].According to a study, Bangladesh ranks as the world's fourth-largest producer of bricks, with an estimated 7,000 to 7,200 brick kilns currently in operation nationwide. These kilns provide employment for approximately one million individuals either directly or indirectly. [6]. Due to a greater concentration of soot particles (BC) and incomplete

combustion in Fixed Chimney Kilns (FCKs), pollution was more noticeable in FCKs compared to Zigzag and Hoffmann kilns [7]. Many brick kilns lack adequate ventilation facilities, leading to ineffective mixing of fuel and air and incomplete combustion of fuel [1]. A study in Gazipur and Rajshahi shows that, the levels of Cr, Fe, and Zn ions among the heavy metals exceeded the acceptable standard limits in soil samples. The concentrations of these heavy metals, namely Cr, Fe, and Zn ions, ranged from 9.50 to 70.13 ppm, 1.12 to 3.03 ppm, and 11.24 to 79.34 ppm, respectively [1].During production seasons at brick kiln areas, fly ash, a byproduct of brick kiln, is disposed of as ash slurry onto nearby land, enriching it with heavy metals like lead (Pb) and chromium (Cr) [1]. Burning soil in brick kilns lowers its pH, leading to acidity, increased sand content, and reduced clay content. This affects soil fertility, productivity, and physical, biological, and chemical properties, making it unsuitable for crop cultivation by removing organic matter [8]. The government should implement effective policies to ensure that the pollution from brick kiln industries is minimum such as operating them away from residential areas. Initiatives such as closing illegal kilns, adopting fixed chimney kilns, and upgrading traditional kilns to modern ones will significantly mitigate pollution [8]. By 2009, over 90% of brick kilns were of the Fixed Chimney Kiln (FCK) type, a number that decreased to approximately 35% by 2017 following the shift to Zigzag Kilns, facilitated by the implementation of the Brick Manufacturing and Brick Kiln Establishment (Control) Act law in 2014.[4] Across the world, rapid urbanization and industrial growth have led to a decline in soil quality, primarily due to accumulation of heavy metals. As an example, about one-sixth (16.67%) of China's arable lands face severe pollution from heavy metal elements, originating from various industrial sources such as emissions, oil operations, mining activities, waste rock stockpiles and many more in different areas [9]. A study in Nepal shows, the soil quality in agricultural fields near active brick kilns in Nepal's Bhaktapur area degraded differently at varying distances (0-50m, 50-100m). This was caused by reduced nutrient levels (like nitrate and sulfate) and increased concentrations of various heavy metals such as chromium (Cr) and lead (Pb) [10]. A study was conducted in Rajshahi and Gazipur, the fly ash samples showed very high level of concentrations of lead (Pb) and chromium (Cr), while the farm soil's pH, organic matter levels, and texture were found to be in critical states [1]. The article has aimed to analyze existing studies to assess soil pollution caused by brick kilns in Bangladesh, with a particular focus on the contamination of heavy metals in agricultural lands. Another goal for the article is to highlight the environmental and health impacts and to recommend mitigation strategies for sustainable brick kiln practices.

2. Method

The study aimed to examine existing literature on soil pollution from brick kilns and the associated health effects in different regions of Bangladesh. A search was conducted in March 2024 using Google Scholar with relevant keywords, out of 150 initially identified papers, 21 were selected based on their relevance to Bangladesh, which focuses on brick kiln-related soil pollution and health effects due to these. The review mostly focuses on studies from regions near major brick kiln clusters in Dhaka City while acknowledging gaps in data from other cities. Data were analyzed and summarized in tabular form to provide a clear overview of the extent of soil pollution and its health effects in different areas of Bangladesh.

3. Result and Discussion

Table 1. highlights the composition of various pollutants including pH, arsenic, cadmium, calcium, chromium, iron, copper, zinc, manganese, potassium, and lead, offering a detailed analysis of soil quality near various brick kiln sites across different cities of Bangladesh. The analysis was conducted on soil samples ranging from 8 to 30.The optimal pH range for nutrient availability, microbial activity, and soil structure is between 6.0 and 7.0 [22] although the result showed that in most of the places the pH level was much lower than the optimal value. Correlation analysis showed that Pb and Cd increased with a decreasing pH and the same result was observed here [12]. The lowest level of pH was in Mawna,Gazipur and the highest was in Rajshahi [12], [19]. Productive agricultural land (PAL) soils were slightly acidic to neutral (pH 5.65 - 7.07), while top soil removal land (TRL) soils were neutral to slightly alkaline (pH 7.30 - 7.80) [16]. The mean value of pH was lower in PAL land than in TRL [17]. Sikdar et al. (2015) and Sikdar et al (2016) determined the pH, Fe and Cu level of Noyadingi, Mawna and Kamlapur of Dhaka district. The soil samples were collected from four different distances which are 250m, 500m, 1000m and 1500m away from each brick kiln and the data represented in the table as mean value. In the study area, the values of OM and nutrients were found very low in the burnt soil compared to the unburnt soil, while the soil pH and EC were relatively higher [15]. The study revealed that in the farm soils of Gazipur contamination levels and ecological risk factors followed the order: Cd > As > Pb > Cr > Zn [19] .The concentration level of cadmium (mean 2.82 $mg.kg^{-1}$) resulted to be very high than its threshold limit (1.40 mg.kg−1) in the majority of the sampling locations [13]. The Arsenic level was found higher in Dhaka region and lower in Rajshahi and same goes for the Cadmium level. Highest amount of Calcium was in Ashulia, Dhaka and lowest was in Nagarpur, Tangail. Chromium level was higher in Dhaka region and lower in Rajshahi. Similar

findings were observed for Iron level although the highest amount was found in Ashulia, Dhaka. In addition, Copper level was the highest in Dhaka region and the lowest in Rangpur. Zinc and Manganese level were also way above in Dhaka region than Rajshahi and Rangpur region. The concentration of Potassium was found higher in TRL as compared to PAL.

Fig. 1. shows a bar chart that compares the maximum concentrations of five heavy metals Cadmium, Chromium, Copper, Zinc, and Arsenic across Dhaka, Rangpur, and Rajshahi. Two major divisional cities, Dhaka and Rajshahi display significantly higher levels of heavy metals, particularly Zinc and Chromium, whereas Rangpur shows much lower concentrations of all the metals analyzed.

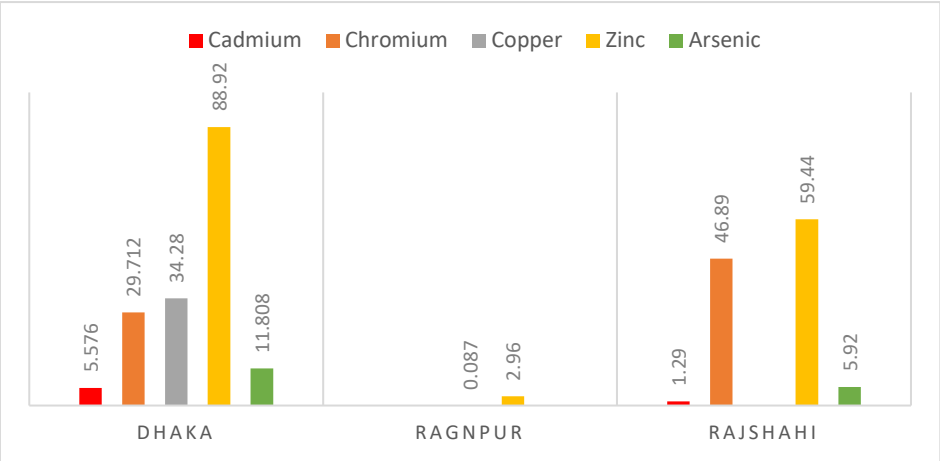


Fig. 1. Maximum values of Heavy metals (ppm)

Table 1. Composition of soil pollutants near the areas of brick kiln cluster of different cities

Division	Author And year	Location	Type of survey	Sample rate	Soil Pollutants and % composition										
					p^H	As (ppm)	Cd (ppm)	Ca (ppm)	Cr (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	K (ppm)	Pb(ppm)
Chittagong	Sarker et al. 2021[11]	Raozan Upazila, Chittagong	Field	N/A	5.35± 0.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dhaka	Sikder et al. 2015[12]	Noyadingi ,Mawna ,Kalampur	Field	N/A	Noyadingi: 6.345 Mawna: 5.37 Kamlapur: 5.025	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Haque et al. 2022[13]	Ashulia, Dhaka	Field	8	6.03±0.129	8.46± 3.348	2.82±2.756	477.87 ±524.9	24.32 ±5.392	31,993.53±5218.606	23.82±10.463	63.07 ±14.374	469.33 ±96.347	N/A	N/A
	Sikder et al. 2016[14]	Noyadingi, Mawna, Kamlapur	Field	N/A	N/A	N/A	N/A	N/A	N/A	Mawna: 304 Noyadingi 1186.75 Kamlapur: 307.5	Mawna: 17 Noyadingi 24.5 ± .5 Kamlapur: 18.5 ± 1	N/A	N/A	N/A	N/A
	Mamun et al. 2015[15]	Kalihati, Tangail, Dhaka	N/A	10	Burnt soil 6.91 ± 0.27 Unburnt soil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

					5.92 ± 0.28									
	Sirajul et al. 2017[16]	Nagarpur Upazila,Tangail, dhaka	N/A	10	6.19±0.43 (PAL) 7.54±0.16 (TRL)	N/A	N/A	6.36±0.93 (PAL) 1.25±0.44 (TRL) (Meq/100g soil)	N/A	N/A	N/A	N/A	N/A	0.16 ±0.03 (PAL) 0.09±0.04 (TRL) (Meq/100g soil)	N/A
	Kumar et al. 2020[17]	Nagarpur region, Tangail, Dhaka	N/A	30	6.19±0.43 (PAL) 7.54±0.16 (TRL)	N/A	N/A	6.36±0.93 (PAL) 1.25±0.44 (TRL) Meq/100g soil	N/A	N/A	N/A	N/A	4.14±0.74 (PAL) 3.80±0.64 (TRL) Meq/100g soil	0.16±0.03 (PAL) 0.09±0.04 (TRL) Meq/100g soil	N/A
	Titu. et al. 2022[18]	Savar, Aminbazar, Ashulia and Boshila	N/A	N/A	N/A	9.51	2.16	N/A	31.94	3.26	N/A	88.92	N/A	N/A	18.59
	Saha et al. 2021[19]	Gazipur	Survey	N/A	7.44 ± 0.50	2.02 ± 0.53	1.19 ± 0.24	N/A	37.61 ± 13.94	2.16 ± 0.34	N/A	40.58 ± 20.41	N/A	N/A	11.53 ± 5.09
Rangpur	Hasan. 2018[20]	Kurigram district	N/A	24	Burnt: 5.29 Unburnt 5.73	N/A	N/A	N/A	N/A	N/A	Burnt:0.075±0.003 Unburnt: 0.084±0.003	Burnt :2.063±0.023 Unburnt:2.59±0.37	N/A	N/A	N/A
Rajshahi	Sakib et al. 2017[21]	Joypurhat, Rajshahi	N/A	10	5.255± 0.8113	N/A	N/A	N/A	34.09 ± 12.88	N/A	6.2065± 2.49	0.7485±0.862	N/A	N/A	2.395± 2.208
	Saha et al. 2021[19]	Rajshahi	Survey	N/A	7.67 ± 0.46	5.01 ± 0.91	0.97 ± 0.32	N/A	26.77 ± 12.22	2.02 ± 0.47	N/A	41.23 ± 18.21	N/A	N/A	16.66 ± 5.81

Note: PAL- Productive agricultural land, TRL- Top soil removed land, N/A – Not Available

Table 2. summarizes the effects of soil pollution around brick kilns in Bangladesh, showing decrease in essential soil elements such as organic matter, nitrogen, phosphorus, potassium, sulfur, organic carbon, calcium, magnesium, and trace metals. Brick kilns, which typically occupy 1.45792 acres (0.59 hectares) of land, contribute to an average crop loss of $1845.24 per hectare due to topsoil depletion [23], [24]. The overall study stated that the status of Percent organic matter (OM), total nitrogen (N), available phosphorus (P), exchangeable potassium (K), available sulfur (S), available zinc (Zn), available boron (B), magnesium (Mg) and calcium (Ca) were decreased in top soil removal land and the mean status of these nutrients were very low [24]. The study's findings demonstrated that in productive agricultural land (PAL), the mean contents of pH, organic matter (OM), potassium (K), magnesium (Mg), calcium (Ca), nitrogen (N), phosphorus (P), sulfur (S), boron (B), and zinc (Zn) were pH:6.19, OM:2.49%, K:0.16 Meq/100g soil, Mg:4.35 Meq/100g soil, Ca:6.36 Meq/100g soil, N:0.14%, P:3.34 ppm, S:22.8 ppm, B:0.28 ppm, and Zn:3.80 ppm, respectively. In the top soil removal land (TRL), the following values were found: pH, OM, K, Mg, Ca, N, P, S, B, and Zn; pH:7.54, OM:0.92%, K:0.09 Meq/100g soil, Mg:1.26 Meq/100g soil, Ca:1.25 Meq/100g soil, N:0.05%, P:4.82µg/g, S:35.07µg/g, B:0.42 ppm, and Zn:4.14ppm,

respectively. The results of the entire investigation showed that while the soil nutrients in TRL were not within the appropriate range for agricultural production, the soil nutrients in PAL were mostly within the limit [25]. A study states that the organic carbon (OC) levels in the soils near brick kilns were poor but gradually improved with increasing distance from the kilns. Organic carbon variations are directly related to surface soil removal processes and the same goes for nitrogen(N), phosphorus(P) and potassium(K) [26]. Hossain et al. (2015) described the soil conditions and their concentrations of different heavy metals near 121 brick kilns of Rangpur division. The soil samples were collected from four different distances which were adjacent to the brick kiln, mid layer of soil, 100m away from brick kiln and 500m away from the brick kiln and the data represented in the table as mean value. According to Bangladesh Brick Manufacturing Owners Association around 7,000 brick kilns in the country currently consume over 1.27 billion cubic feet of topsoil every year. Brick kilns had a negative effect on agricultural productivity and are certainly affecting the potential of arable lands since the table showed that the helpful soil elements had reduced drastically near the brick kilns [27]. The contamination of heavy metals such as lead (Pb), chromium (Cr), nickel (Ni), zinc (Zn), copper (Cu) in the plant tissue confirming that the brick kilns were not only polluting the surrounding soil but also the other natural elements [28]. The present study revealed that brick manufacturing through burning caused huge losses of fertile agricultural lands as well as nutrients in the central region of Bangladesh.

Fig. 2. shows the maximum organic material availability in soil around the brick kilns. Where the maximum amount is available in Dhaka division and lowest in Rajshahi division. The values of Chittagong and Rajshahi division is only based on SOC (soil organic Carbon), so the result may vary with actual numbers. The overall scenario shows the amount of organic material available in soil around the brick kilns is inadequate.

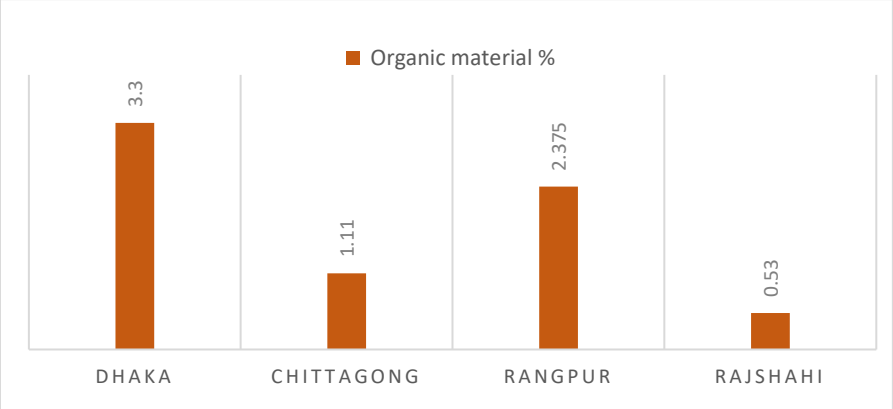


Fig. 2. Organic material %

Table 2. Table for effects of soil pollutants and other problems of brick kilns on human health

Division	Author and Year	Location of Study	Type of survey	Sample Rate	Effects of Soil Pollution (% if available)									
					Crop Loss	Land Degradation	Total Organic material	Total Nitrogen Availability (ppm)	Total Phosphorus Availability (ppm)	Total Potassium Availability (ppm)	Total Sulphur Availability (ppm)	Total Calcium Availability (ppm)	Total Magnesium Availability (ppm)	Total Zinc Availability (ppm)
Dhaka	Rahman et al. 2015[23]	50 Upazilas	Field survey	N/A	N/A	1.433acres Per brick kiln	N/A	67% (D)	67% (D)	87% (D)	33% (D)	N/A	N/A	N/A
	Kunar et al. 2020[24]	Tangail	Field survey	30	1845.24$ Net loss Per hector	N/A	2.49±0.%(PAL) 0.92±.42 (TRL) %	0.14±.02 (PAL) .053±.025 (TRL) %	4.82±2.30 (PAL) 3.34±1.36 (TRL) ppm	0.16±0.03(PAL) 0.09±0.04(TRL) meq/100	35.07±6.85(PAL) 22.8±7.25(TRL) ppm	6.36±.93 (PAL) 1.25±0.44 meq/100g (TRL)	4.35±0.78 (PAL) 1.26±0.57 (TRL)meq/100g	4.14±.74(PAL) 3.80±.64 (TRL)
	Sirajul et al. 2017[25]	Kalihati, Tangail	Field survey	30	N/A	12355.269 acres Topsoil Lost	1.65 – 3.30%(PAL) 0.40 - 1.99% (TRL)	0.8 - 0.18%(PAL) 0.03 – 0.12% (TRL)	1.4 – 8.70(PAL) 1.2 -5.96 (TRL)	0.11 -0.23 (PAL) 0.03-0.19(TRL) Meq/100g	23.37 – 47.95(PAL) 15.20 - 37.43 (TRL)	5.00 - 7.50(Pal) 0.60-2.00(TRL) Meq/100g	3.30-5.50(Pal) 0.50-2.50(TRL) Meq/100g	3.30-5.90(PAL) 2.90-5.10(TRL)

Chittagong	Raihan et al. 2021 [26]	Raojan, Ctg.	Field Work, Info of DoE	72 respondent, 62 crop fields	N/A	N/A	.96%±0.15(SOC)	3.34 % ±15.63	27.83±15.63	.15±.03 (cmol/l)	N/A	N/A	N/A	N/A
Rangpur	Hossain et al. 2015[27]	Rangpur	Soil samples were analysed by the central laboratory of SRDI, Dhaka	121 brick kilns	N/A	N/A	0.7925 %	0.078	26.0025	0.1625 (meq/100gm)	28.495	N/A	N/A	0.93
		Nilfamari			N/A	N/A	0.875 %	0.171	28.9775	0.2925	57.7525	N/A	N/A	1.8
		Kurigram			N/A	N/A	2.3725	0.119	10.93	0.2	105.2	N/A	N/A	1.81
		Lalmonirhat			N/A	N/A	1.275	0.065	10.93	0.098	30.02	N/A	N/A	0.735
		Gaibandha			N/A	N/A	1.025	0.204	9.005	0.1275	4.155	N/A	N/A	0.911
Rajshahi	Tamzid et al. 2017 [28]	Joypurhat	Field survey	N/A	N/A	N/A	0.15-0.53%.(SOC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note: C- Close to the brick kiln, D- Decrease of that content, F- Far from the brick kiln, PAL-Productive Agricultural land, TRL- Top soil removal land, SOC- Soil organic carbon, N/A – Not Available.

4. Conclusion

This review has brought to light the severity of soil pollution and the significant environmental impacts linked to Bangladesh's brick kilns. The rapidly expanding brick industry employs mostly FCK technology, which is antiquated and extremely polluting. The primary objective of this review was to highlight the pollution caused by brick kilns in their surrounding areas, including the reduction of essential soil elements and the increasing contamination of heavy metals in agricultural lands. The current scenario of soil pollutants is very alarming as the data shows. At distances of 100-200 meters, pollutant concentrations remain significantly high, although they decrease with distance. The existence of these harmful metals reduces vital nutrients, raises soil acidity and salinity, and severely affects soil organisms, leading to decreased fertility and quality. However, there isn't enough data available to represent the entire country's scenario because the papers found contain data from only some divisions and cities. Further research can be done in major cities to reveal the actual scenario. To overcome the situation, the government can implement laws that restrict the release of harmful gases, heavy metals, and particulate materials from brick kilns, adopting new greener technologies like zig-zag brick kilns, offering financial incentives and assistance to retrofit conventional kilns with emission control equipment like electrostatic precipitators, scrubbers, and filters. The government can also collaborate with researchers and fund them to develop innovative solutions to reduce pollution from brick kilns, such as cleaner fuel alternatives or advanced kiln designs.

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