

Environmental Degradation and Sustainable Development: A Case Study of Brick Kilns in Palasbari Revenue Circle, Assam

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Abstract

Environmental pollution poses a serious threat to human development by adversely affecting both the physical and mental well-being of people. Changes in the physical, chemical, and biological components of the environment have made human survival increasingly challenging. A clean and pollution-free environment is therefore essential for human existence, as a healthy environment alone can ensure a better quality of life. Among small-scale industries, brick kilns play a significant role in meeting construction demands. However The Central Pollution Control Board (CPCB), Delhi, has recognized the brick production industry as highly resource and energy intensive as well as polluting industry, primarily due to obsolete and traditional production techniques used in India. The brick kilns are source of local air pollution, land degradation and water pollution which ultimately affect the local population, agriculture and vegetation and also contribute to climate change at global level. This paper examines the environmental impacts of brick kilns in the Palasbari Revenue Circle, Assam, focusing on air, soil, and water degradation and their implications for sustainable development.

The study is based on primary data collected through field surveys, interviews and observations, supported by secondary data from government reports and published literature. The study highlights the need for adopting cleaner technologies, enforcing environmental regulations, and promoting sustainable alternatives in the brick-making sector.

Keywords: *Environmental Degradation, Sustainable Development, Brick Kilns, Air, Water and Soil Pollution.*

1. Introduction

Over the past few decades, environmental pollution has increased significantly due to the pollutants released into the air, water and soil. This rise in pollution is largely linked to rapid population growth, expanding industries, urban development, mechanisation, excessive use of chemical fertilisers and pesticides in agriculture, and improper disposal of human waste. Continuous environmental degradation has become a major obstacle to achieving sustainable development, as it negatively affects agriculture, industry, and livestock production. In India, the brick industry is one of the largest producers of clay fired bricks in the world, ranking second after China and contributing more than ten percent of global production. However, brick manufacturing is considered a highly resource-intensive and polluting industry by the Central Pollution Control Board. (CPCB). In the Palasbari Revenue Circle, brick kilns are among the main sources of environmental pollution. Emissions from these kilns deteriorate air quality, excessive removal of clay reduces soil fertility, and poor waste management contaminates nearby water bodies, posing risks to ecosystems as well as human health. Although brick kilns create employment opportunities and contribute to local economic growth, many of them have yet to adopt sustainable practices. In this context, examining the environmental impacts of brick kilns becomes essential for developing balanced development strategies. This paper aims to analyze the extent of environmental degradation caused by brick kilns in the Palasbari Revenue Circle and to assess their implications for sustainable development. The study highlights the need for cleaner technologies, effective environmental regulations, and sustainable alternatives to ensure environmental protection while maintaining economic benefits.

1.1 Meaning of Sustainable Development

In 1987 the “brundland commission” set up by the United Nations (UN) published their report as “our common future” and defined “sustainable development” for the first time as “development that meets the need of the present without compromising the ability of the future generation to meet their needs” It aims to secure the needs of society, its welfare, security, safety and prosperity, without compromising the ability of future generations to achieve this in the future.

1.2 Brick Industry of Palasbari Revenue Circle

A considerable number of brick kilns have been established in various parts of the Palasbari Revenue Circle in recent years. According to data obtained from the Palasbari Revenue Circle office, a total of 13 brick kilns exist within the circle, out of which 12 are currently operational. These functioning units are distributed across three development blocks: 4 kilns in Rampur Development Block, 7 kilns in Chhayani Development Block, and 1 kiln in Rani Development Block. Together, these kilns produce approximately 45–50 million bricks during a single production season to meet the construction needs of the circle and nearby areas. The industry also provides seasonal employment to nearly 2,000 workers. Brick manufacturing in this region is largely seasonal and usually takes place during the winter months, beginning in October and continuing until the middle of April.

Brick kiln labourers in the study area largely consist of migrant families, many of whom bring their children along during the working season. Each year, a significant number of workers migrate from states such as Uttar Pradesh, Bihar, and Jharkhand, as well as from backward districts of Assam including Dhubri district and Barpeta district. These migrant labourers usually reside within the kiln premises in temporary shelters made of brick or bamboo walls and roofs covered with galvanized tin sheets. Most of the migrants are landless labourers or marginal farmers who arrive before November to work in the brick kilns of the Palasbari Revenue Circle. Recruitment is generally carried out through labour contractors, locally known as “sardars,” who provide advance payments to workers. In return, the labourers are expected to report for work at the beginning of the following brick-making season to repay the advance. Field survey findings indicate that all 12 operating brick kilns in the area (100%) use

the Fixed Chimney Bull's Trench Kiln (BTK) technology. No evidence was found of other kiln types such as moving chimney BTK, Vertical Shaft Brick Kiln (VSBK), High Draught Kiln, or Habla Kiln in the Palasbari Revenue Circle.

Table 1.2: Brick Kilns in Palasbari Revenue Circle with their Labour Employment and Productivities

Sl No.	Name of the Brick Kilns	Year of Establishment	Ownership	No. of Workers Employed		Production Level Per Season (in lakhs)
				Permanent	Temporary	
1	CBI	1995	Proprietorship	6	175	50
2	JRK	2005	Proprietorship	6	200	70
3	MAA	2005	Proprietorship	6	180	40
4	MDB	2005	Proprietorship	5	160	50
5	HSI	2012	Partnership	5	80	20
6	BPR	2010	Partnership	7	120	30
7	HMB	2010	Proprietorship	5	40	10
8	GBI	2005	Proprietorship	6	144	50
9	NBI	1992	Proprietorship	5	125	40
10	TBI	2010	Partnership	5	125	30
11	PLB	1996	Proprietorship	4	100	25
12	SBI	2013	Proprietorship	5	150	40

Source: Compiled from field survey, Records of Sub- Divisional Circle Office, Palasbari.

1.3 Review of literature

Environmental protection plays a crucial role in the development process, as it supports the sustainable use of resources and improves overall human well-being. According to UNESCO, safeguarding the environment is essential for achieving sustainable development goals (<http://www.unesco.org>). A significant milestone in this regard was the United Nations Conference on the Human Environment held in Stockholm in 1972, which brought together representatives from 113 countries along with participants from 19 international organizations. This was the first global conference dedicated entirely to environmental concerns. During the conference, a panel of 27 experts highlighted the strong interdependence between

environmental protection and economic development, pointing out that although conflicts may arise in specific situations, both are fundamentally interconnected and should be understood as complementary aspects of progress (**Vogler, 2007**).

Rapid industrial growth in developing nations such as India has significantly increased environmental stress, particularly from small-scale industries like brick kilns. These kilns are considered major contributors to air pollution in South Asia. Conventional technologies, including Fixed Chimney Bull's Trench Kilns (FCBTK), release substantial amounts of pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and black carbon (**CPCB, 2017; World Bank, 2020**). Additionally, the United States Environmental Protection Agency (EPA) has noted that brick manufacturing contributes to climate change through the release of carbon dioxide and black carbon. In India, the industrial sector is responsible for around 15% of total black carbon emissions, with approximately two thirds of those emissions i.e. 9% attributable to brick kilns.

A study by **Joshi and Dudani (2008)** examining the environmental health impacts of brick kilns in the Kathmandu Valley revealed that children studying in schools located near brick kilns experienced poorer health compared to those attending schools situated farther away. The research also identified a higher occurrence of respiratory illnesses, including tonsillitis and acute pharyngitis, among students living and studying in areas close to these kilns.

Skinder et al. (2014) investigated air pollution generated by brick kilns in Panzan village, Budgam district of Jammu and Kashmir. To assess the levels of gaseous pollutants, emissions were monitored at eight-hour intervals during both operational and non-operational periods of the kilns. The findings indicated that concentrations of pollutants such as sulphur oxides (SO_x), nitrogen oxides (NO_x), respirable particulate matter (RSPM), non-respirable suspended particulate matter (NRSPM), and total suspended particulate matter (SPM) exceeded the limits set by the National Ambient Air Quality Standards (NAAQS) when the kilns were in operation. Based on these observations, the study recommended adopting cleaner production methods, including the use of vertical shaft brick kilns (VSBK) as an alternative to traditional Bull Trench Kilns (BTK).

Beyond their role in air pollution, research also points to the harmful impact of brick kilns on soil and water resources. The extraction of topsoil for brick production and associated excavation activities lead to a decline in soil organic matter, nutrient levels, and moisture content, while increasing electrical conductivity—signs of declining soil health. This degradation reduces land productivity and poses a serious risk to long-term agricultural sustainability, particularly in areas where brick kilns operate close to farmland (**Jeet et al., 2021**).

Singh and Asgher (2005) analyzed changes in land use and land cover in areas surrounding brick kilns near Aligarh city, India. Their findings showed that brick production leads to the degradation of fertile agricultural land and disrupts established land use patterns in villages where these kilns operate.

Khan and Vyas (2008) investigated the impact of the brick industry on the water quality of the Kshipra River and observed that these activities have detrimental effects on soil, water, air, vegetation, and human health in the surrounding region. The study noted that brick kilns consume large quantities of fuel and rely on inefficient production methods, which contribute to significant air pollution and harm both plant life and human well-being. Furthermore, it was found that waste materials from the kilns are discharged into the river, leading to increased levels of total solids, suspended solids, reduced dissolved oxygen, and higher calcium hardness in the water.

In addition to environmental concerns, existing studies highlight the wider socio-economic implications of brick kiln operations. A bibliometric and thematic analysis by **Parvez et al. (2023)** indicated that the adverse effects of this industry also impact human health, sustainable livelihoods, and social well-being. The review further pointed out serious challenges in poorly regulated settings, including exploitative labour practices and conditions resembling modern slavery.

1.4 Objectives

- To identify the different environmental pollutions created by the brick kilns of Palasbari Revenue Circle.
- To assess the impact of environmental pollutions on human health and vegetation caused by brick kilns of Palasbari Revenue Circle.

- To examine whether existing environmental regulations and practices are properly implemented to control pollution and protect the environment.
- To recommend sustainable strategies and policy measures for promoting sustainable development in brick kiln industries of Palasbari Revenue Circle.

1.5 Research Methodology

- a. Nature of Study:** The present study is descriptive as well as Analytical in nature.
- b. Area of study:** The area of the study is Palasbari Revenue Circle. It comprises of approx. 374.57 sq. km. geographical area and is one of the twelve revenue circles comprising the district of Kamrup in Assam. The circle is situated in the south bank of river Brahmaputra and situated almost 30 km away from Guwahati city. The circle has 190 revenue villages and 20 forest villages. It has one Municipal Board (Palasbari Municipal Board) with 10 wards. As of the 2011 Census, the Palasbari Revenue Circle has a total population of 239,026, comprising 121,926 males and 117,100 females, with a sex ratio of 960. The average literacy rate is 79.95% with 76.19% male and 65.98% female literacy rate.
- c. Research Design:** In Palasbari Revenue Circle twelve brick kilns are in operation and all of these brick kilns are taken for the study. First data and information have been collected from each of the twelve (12) owners of brick kilns. Secondly, a few focused people have been consulted in the areas close to the brick kilns for collecting information regarding the impact of brick kilns on human health, crop productivity, livestock etc. For this purpose three focused group discussions have been arranged in different areas. Such a focused group comprises of heads of the village (Gaonburha), a few teachers of nearby schools, a few social workers of the locality, a few members of Mahila Samities, Panchayat Secretaries, NGO People and a few progressive farmers.

Table 1.5: Members of Focused Group Discussion

Sl No	Focused people	Numbers	Remark
1	heads of the villages (Gaonburha)	05	One from each cluster of villages where kilns are concentrated.
2	Teachers	03	One from each development block.
3	Social Workers	03	One from each development block.
4	Mahila Samity Members	03	One from each development block.
5	Panchayat Secretary	03	One from each development block.
6	NGO People	03	One from each development block.
7	Progressive farmers	05	One from each cluster of villages where kilns are concentrated.
Total		25	

d. Data Collection: Both primary and secondary data have been collected for the study. The primary data are collected by the technique of field survey, interviewing all categories of respondents administering questionnaires among them. Secondary data are collected from various offices and libraries viz. Sub Divisional Office, Palasbari, District Industrial Centre, Ghy, Pollution Control Board, Ghy, Office of Chief Inspector of Factories, IIE (Guwahati), OKDISCD (Guwahati). Moreover different books, newspapers, official reports, journals and websites are also consulted for the present study.

2. Air Pollution Created by Brick Kilns of Palasbari Revenue Circle and its Effect

Air pollution is an atmospheric condition in which certain substances like gases, particles and biological molecules are present in concentration high enough above their normal ambient levels which can cause measurable effects on man, animals, vegetation or materials (Kaushik & Kaushik, 2012).

Brick kiln emissions consist of a variety of pollutants generated during both complete and incomplete combustion processes

involved in firing raw (kutcha) bricks. These emissions originate not only from the fuels used but also from the raw materials themselves (RERIC, 2003; Zhang, 1997). Pollutants are released through chimney (stack) emissions as well as fugitive sources, and typically include fine coal particles, dust, organic matter, and various gases. Once emitted, these pollutants are dispersed by wind into surrounding areas, leading to a decline in local air quality. In addition, several stages of brick kiln operations—such as clay excavation, fuel feeding, coal crushing, ash handling and spreading, and the loading and unloading of bricks—contribute significantly to dust generation and overall air pollution.

2.1 Air Pollution Due to Use of Coal in the Brick Kilns

The combustion of large quantities of coal and wood in brick kilns leads to significant air pollution, which negatively affects the health of nearby residents as well as kiln workers. It also poses serious risks to local vegetation and agricultural productivity. The extensive use of coal in these kilns results in the release of pollutants such as carbon dioxide (CO₂), carbon monoxide (CO), sulphur dioxide (SO₂), nitrogen oxides (NO_x), and particulate matter (PM), including black carbon (BC). These pollutants are emitted in the form of smoke, fumes, dust, soot, and ash, contributing to environmental degradation.

In the Palasbari Revenue Circle, brick kilns primarily rely on coal as the main fuel for firing bricks. During the initial stages of the process, firewood is also used to remove excess moisture from the raw bricks. On average, about 25–30 tonnes of coal are consumed for producing one lakh bricks, with supplies sourced from Assam and Meghalaya. The level of air pollutant emissions varies considerably among kilns during a typical firing cycle of about seven days. According to Le and Oanh (2010), the average emissions per 1,000 bricks are estimated at 6.35–12.3 kg of carbon monoxide (CO), 0.52–5.9 kg of sulphur dioxide (SO₂), and 0.64–1.4 kg of particulate matter (PM). On an average the brick kilns of Palasbari Revenue Circle produce three to four million pieces of bricks in a season. This large-scale production results in the release of substantial amounts of CO, SO₂, and particulate pollutants into the atmosphere, contributing to air pollution. The quantities of these emissions from different kilns in the study area are presented in Table 2.1

Table 2.1: Annual Coal Consumption and Emissions of Pollutants from the Brick Kilns of Palasbari Revenue Circle

Brick Kilns's Name	Brick Production (in lakhs)	Consumption of Coal (in tons)	Carbon Monoxide (CO) Emission (in kg)*	Sulphur Dioxide (SO₂) Emission (in kg)*	Particulate Matter (PM) Emission (in kg)*
CBI	50 lakhs	1500	31,750-61,500	2,600-29,500	3,200-7,000
JRK	70 lakhs	2000	44,450-86,100	3,640-41,300	4,480-9,800
MAA	40 lakhs	1100	25,400-49,200	2,080-23,600	2,560-5,600
MDB	50 lakhs	1200	31,750-61,500	2,600-29,500	3,200-7,000
HSI	20 lakhs	620	12,700-24,600	1,040-11,800	1,280-2,800
BPR	30 lakhs	840	19,050-36,900	1,560-17,700	1,920-4,200
HMB	10 lakhs	300	6,350-12,300	520- 5,900	640-1,400
GBI	50 lakhs	1350	31,750-61,500	2,600-29,500	3,200-7,000
NBI	40 lakhs	1200	25,400-49,200	2,080-23,600	2,560-5,600
TBI	30 lakhs	840	19,050-36,900	1,560-17,700	1,920-4,200
PLB	25 lakhs	750	15,875-30,750	1,300-14,750	1,600-3,500
SBI	40 lakhs	1200	25,400-49,200	2,080-23,600	2,560-5,600
Total	455 lakhs	12, 900	2,88,925-5,59,650	23,660-2,68,450	29,120-63,700

**Calculation is done on the basis of estimation given by Le and Oanh (2010).*

The data presented in the table indicate that, in the surveyed brick kilns, annual carbon monoxide emissions range from 2,88,925 to 5,59,650 kg, while sulphur dioxide (SO₂) emissions vary between 23,660 and 268,450 kg. Particulate matter (PM) emissions are estimated to lie between 29,120 and 63,700 kg. The total coal consumption across these kilns is approximately 12,900 tonnes. These figures suggest that the high level of coal usage in the area contributes significantly to elevated concentrations of air pollutants within the circle.

Most brick kilns in the Palasbari Revenue Circle depend on coal sourced from Assam and Meghalaya for firing green bricks. The coal from these regions is known for its relatively high sulphur content. While sulphur levels in Indian coal generally range between 0.1% and 0.8%, coal from Assam contains significantly higher levels, reaching up to 3.9% (Coal Atlas of India, 1993). Studies by Barooah and Baruah (1996) further indicate that coal from northeastern India typically contains between 2.7% and 7.8% sulphur, with a significant share (approximately 75% to 90%) present in organic form. The use of such high-sulphur coal is environmentally harmful, as its combustion releases sulphur dioxide (SO₂), a toxic and corrosive gas that contributes to acid rain and poses serious health risks.

2.2 Solid Waste Generation

Coal ash is the main form of solid waste produced in brick kilns, and its quantity depends on the volume of coal used and its ash content. In addition, a significant amount of waste is generated in the form of over-burnt, under-burnt, and broken bricks, which are usually accumulated near the stockyard. To provide thermal insulation, much of the ash is reapplied to the top layer of the kiln and, at times, along its walls. The process of unloading fired bricks, along with the removal of ash from the kiln surface, also creates substantial dust. As ash and dust remain deposited on the kiln top and walls, even light winds can easily disperse these particles into nearby areas. If not regularly cleared or properly managed, this accumulation can make the kiln environment extremely dusty.

2.3 Air Pollution Due to Use of Traditional Technology

The continued use of outdated and inefficient firing technologies, along with the absence of proper emission control systems, leads to the release of large amounts of air pollutants. A notable example of such inefficient technology is the Fixed Chimney Bull's Trench Kiln (FCBTK). This type of kiln operates as a continuous, moving-fire system that relies on natural draught created by a fixed chimney and is comparatively more resource- and energy-intensive than modern alternatives. According to the World Bank (2007), Moving Chimney Bull's Trench Kilns emit about 8.06 kg of suspended particulate matter (SPM) per 1,000 bricks, whereas Fixed Chimney kilns release around 1.71 kg, and Vertical Shaft Brick Kilns (VSBK) emit only 0.55 kg for

the same output. This indicates that fixed chimney kilns are nearly five times cleaner and VSBK over fourteen times cleaner than traditional kiln types. In the Palasbari Revenue Circle, brick production is largely carried out using FCBTK technology, which is associated with incomplete fuel combustion, black smoke emissions, and the accumulation of unburnt coal residues within the kiln. Such incomplete combustion results in high emissions of suspended particulate matter (SPM) and black carbon (BC), with SPM concentrations typically ranging between 150 and 1250 mg/Nm³ (GKSPL, 2011).

The brick kilns surveyed do not have adequate arrangements for handling or storing toxic by-products generated during combustion. From October to April, the surrounding areas are heavily affected by the persistent smell of burning coal and other materials. With the beginning of the monsoon season in May/June, the brick kilns stop its functioning. During this inactive period, residual pollutants gradually settle and disperse into the surrounding soil and vegetation.

2.4 Effects of Air Pollution:

Deterioration of air quality poses serious risks to both human health and the environment. According to estimates by the World Health Organization, air pollution is responsible for around three million deaths annually, with nearly eight lakh premature deaths attributed to conditions such as respiratory diseases, lung cancer, and cardiovascular disorders. A significant share of these health impacts is linked to exposure to outdoor air pollution (WHO, 2000). Exposure to polluted air can affect multiple body systems, including the respiratory, cardiovascular, urinary, digestive, and nervous systems (Nilsson, 2015). High concentrations of coal dust and particulate matter can also reduce visibility and lead to skin irritation. Beyond its impact on human health, air pollution adversely affects ecosystems by contributing to problems such as acid rain, ozone layer depletion, and damage to crops, trees, and wildlife. It can also disrupt aquatic ecosystems by harming fish and other organisms. Acid rain can alter the chemical composition of soil, making it less suitable for organisms that rely on it for habitat and essential nutrients.

Brick kiln dust contains various elements such as calcium (Ca), sodium (Na), cadmium (Cd), zinc (Zn), magnesium (Mg), chloride (Cl), sulphur (S), molybdenum (Mo), along with

elevated levels of phosphorus (P) and potassium (K), making it as harmful as smoke emissions. This dust is alkaline in nature, with a pH range of 8.2 to 10.5. Such characteristics can adversely affect plant growth, particularly by interfering with their maturation process (Upadhyay, 2004).

Air pollution from brick kilns also has a significant impact on workers' health. Long working hours expose them to high levels of dust, increasing their risk of health problems. In the Palasbari Revenue Circle, workers face multiple health hazards as they both work and reside within the kiln premises, often just a few meters away from the emission sources. Many workers live on-site with their families, including women and children, which further exposes them to health risks from pollution. Labourers are involved in activities such as moulding raw bricks, crushing coal, feeding fuel, and loading and unloading bricks, all of which contribute to dust exposure. Workers in the brick kilns of the Palasbari Revenue Circle face various health issues, largely due to the highly unhygienic conditions present at the kiln sites. Field observations indicate that kiln owners have largely failed to implement adequate safety measures to protect workers from the harmful effects of air pollutants.

During focus group discussions, most participants identified brick kilns as the primary source of air pollution in the area. They reported that emissions from these kilns are linked to several health issues among local residents, including breathing difficulties, eye irritation, nasal problems, and skin diseases. Beyond health impacts, the community also reported concerns such as declining groundwater availability and reduced agricultural yields. Vegetation near the kilns appeared weakened and degraded. Some villagers mentioned that dust from the kilns settles on clothes during sun-drying, leaving dark stains. Additionally, the frequent movement of heavy trucks carrying coal, bricks, and soil has led to significant damage to village roads.

3. Land Degradation from the Manufacturing Activities of Brick Kilns and its Effect

In addition to air pollution, the brick industry causes significant harm to agricultural land. Brick kilns require extensive open areas for their operations, and in the Palasbari Revenue Circle, many of them are located within traditional paddy fields.

Continuous firing of bricks leads to the burning of soil layers several feet deep and alters its natural composition. The intense heat also destroys microorganisms in the surrounding soil, accelerating land degradation. As a result the local farmers or the owners of adjacent land are compelled to either sell or lease their land to brick kiln owners. Brick production relies on high-quality loamy soil, which is equally important for agriculture. The climate and soil conditions of the Palasbari area are well-suited for rice cultivation; however, since agriculture is largely rain-fed, fields are mostly left uncultivated during the dry season, with only limited rabi crops and vegetables grown.

Apart from air pollution the brick industry also causes serious damage to agricultural land. Brick kilns require a large amount of open fields for its allied activities. In Palasbari Revenue Circle all brick kilns are situated at the centre of the traditional paddy field. Due to continuous burning of bricks the soil of the kiln burn down up to few feet deep from the top and also changes the soil composition. Moreover the extreme heat burn the micro organism of the land up to few meters from the kiln and the land started to degrade. As a result the local farmers or the owners of adjacent land are compelled to either sell or lease their land to brick kiln owners. The traditional method of making bricks requires good quality loamy soil. Such good quality soil is also used for agricultural purpose. The climatic condition and the soil of Palasbari Revenue Circle are suitable for rice production. Moreover as the agriculture in the study area is only rain-fed, paddy fields are not cultivated during dry season and only a few fields are planted with rabi-crops whereas some fields are also used for vegetables. In the Palasbari Revenue Circle, brick kilns collect soil both from nearby riverine wastelands and by excavating land from adjacent agricultural fields. Focus group discussions revealed that many younger landowners are reluctant to continue farming and instead prefer to lease their land for soil extraction for periods of four to five years, as it provides quicker and higher financial returns compared to agriculture. This practice involves removing the top 4–5 feet of fertile soil, which eventually renders large areas of farmland unproductive and fallow after a few years. Additionally, during the off-season, brick manufacturers often procure soil from distant locations at lower costs and store it for use in the next production cycle.

During field survey it is observed that due to excessive digging of soil the land becomes infertile for which the vegetations has been cut at these sites. The soil quarrying activities also lowered the level of agricultural land by about 2–4 feet compared to surrounding areas and alter the natural composition of the soil. Furthermore, once the soil has been removed, the excavated pits are typically left unattended, rendering the land unsuitable for grazing and other uses.

According to guidelines issued by the Pollution Control Board, the topsoil or humus layer removed during earth extraction and kiln operations should be carefully preserved within the brick field for future land reclamation of exhausted or abandoned kiln sites. However, field observations reveal that, in practice, none of the brick units follow this requirement.

3.1 Quantitative Measurement of Degraded Land in the Study Area

According to the Central Building Research Institute, Roorkee (CBRI, 2001), approximately 0.003 cubic meters of soil is required to produce a single brick. In the Palasbari Revenue Circle, the average production of bricks per kiln are around 4 million in one season. Based on this estimate, each kiln removes nearly 12,000 cubic meters of topsoil annually for brick production. Table 3.1 presents the extent of land degradation (measured in bighas) and the yearly loss of topsoil (in cubic meters) caused by brick kilns in the study area.

Table-3.1: Land Degradation (in bighas) and Annual Loss of Topsoil (in cu. m) Through Brick Kilns of Study Area

Sl No.	Name of the Brick Kilns	Present Land Under brick kilns (in Bigha)	Production of bricks (in Lakhs)	Loss of Top Soil per Season (in cu.m)
1	CBI	48	50	15,000
2	JRK	23	70	21,000
3	MAA	19	40	12,000
4	MDB	17	50	15,000
5	HSI	19	20	6,000
6	BPR	5	30	9,000
7	HMB	26	10	3,000
8	GBI	13	50	15,000

9	NBI	24	40	12,000
10	TBI	17	30	9,000
11	PLB	19	25	7,500
12	SBI	8	40	12,000
Total	-	238	455	1,36,500

The data in the table indicate that brick kilns in the Palasbari Revenue Circle occupy about 238 bighas of land, much of which can be regarded as completely degraded. Additionally, the surveyed kilns collectively use approximately 136,500 cubic meters of fertile topsoil each year for brick production.

3.2 Loss of Soil Fertility

A major consequence of mining and quarrying activities is the decline in soil fertility. These processes bring about significant changes in the physical, chemical, and biological properties of soil, making quarried land less productive. There is a loss of $\frac{3}{4}$ th of soil nutrients was reported due to brick production in different regions of Bangladesh (Khan et al. 2007). Moreover, the continuous heat generated by kilns reduces the moisture content of nearby soil, while unregulated excavation disrupts the natural drainage patterns of the area.

3.3 Erosion Caused by Adjacent Quarried Lands

One of the significant negative impacts of soil quarrying on agricultural land is increased soil erosion. The removal of topsoil makes the land more vulnerable to being washed away by water, especially along sloping areas. Focus group discussions with villagers indicated that a substantial amount of fertile topsoil is also extracted from nearby agricultural fields. Due to this inconvenience, many landowners of the adjacent land are often compelled to lease or sell their land to brick kiln operators.

4. Water Logging

Waterlogging is another major issue associated with quarried land, where the accumulation of rainwater results in flooding. This problem is not confined to the rainy season and may also occur at other times of the year. Extensive soil excavation from agricultural fields can result in both temporary and long-term waterlogging in the study area. In the Palasbari Revenue Circle, temporary waterlogging has been observed in areas surrounding brick kilns, making it difficult for local farmers to cultivate crops in affected fields.

Field observations revealed that quarried lands often turn into deep pits due to the absence of proper leveling. During the rainy season, these ditches are filled with water, creating suitable breeding grounds for mosquitoes and other pests. In some cases, nearby villagers and workers use this stagnant water for activities such as washing and bathing, which can lead to serious health risks. Additionally, these abandoned excavation sites are sometimes used as dumping grounds for waste.

4.1 Water Pollution and its Effect

Dey and Dey (2015) reported that brick kiln activities significantly influence the physical, chemical, and biological characteristics of nearby aquatic systems. Heat released from kiln operations contributes to a rise in water temperature in surrounding water bodies. The study also found increased turbidity in these areas, mainly due to land excavation, sand extraction, and the disposal of ash, which raises the silt content in the water. This elevated turbidity may further contribute to higher water temperatures, as suspended particles absorb and retain heat from sunlight, thereby warming the aquatic environment.

In the Palasbari Revenue Circle, three brick kilns are located within approximately 200–300 meters of the Brahmaputra River. Wastewater generated from these kiln sites contains a high concentration of suspended solids. Additionally, nearby open areas along the riverbank are often used by workers for sanitation purposes, leading to unpleasant odors and unsanitary conditions in the surrounding environment.

Various diseases are transmitted through contaminated water, including typhoid, cholera, infectious hepatitis, and bacillary dysentery. The World Health Organization reports that around 1.1 billion people worldwide lack access to safe drinking water, while approximately 2.4 billion people do not have adequate sanitation facilities. This situation contributes significantly to the spread of both acute and chronic water-related illnesses. It is further estimated that preventable water-borne diseases cause about 3.4 million deaths annually, including a large number of children.

5. Legislative Development Relating to Environment in India as well as in Assam

India has developed an extensive framework of environmental laws to address pollution and conservation issues. Key legislations

enacted after independence include the Air (Prevention and Control of Pollution) Act, 1981; the Environment (Protection) Act, 1986; the Forest (Conservation) Act, 1980; the National Environment Tribunal Act, 1995; the National Environmental Appellate Authority Act, 1997; and the Biological Diversity Act, 2002. In addition, several older laws—such as the Factories Act, 1948; the Mines Act, 1952; the Atomic Energy Act, 1962; the Wildlife (Protection) Act, 1972; the Industrial (Development and Regulation) Act, 1957; and the Indian Forest Act, 1927—have been amended over time to better address emerging environmental challenges.

In Assam, environmental governance is primarily handled by the Department of Environment and Forests and the Assam Pollution Control Board. These bodies function under the guidance of the Regional Office of the Ministry of Environment, Forest and Climate Change located in Shillong, to which matters related to approvals and policy direction are referred. This regional office operates through two main divisions—environment and forestry—while monitoring and regulatory responsibilities are carried out in coordination with the State Pollution Control Board.

The Assam Brick Kilns Establishment and Regulation Rules, 2013 were introduced to control the establishment and functioning of brick kilns with the aim of minimizing environmental impacts. These rules place several restrictions on setting up kilns in the state. Brick kilns are permitted only on land that has been officially classified as non-agricultural by the concerned Circle Officer of the Revenue Department. Additionally, the establishment of a new kiln requires a public hearing in the respective Gaon Panchayat to assess local acceptance, and a No Objection Certificate from the Panchayat is mandatory. The area selected for soil excavation must also comply with the limits specified under Rule 7 of the Assam Minor Mineral Concession Rules, 2013. Furthermore, kiln operators are required to ensure a legitimate and sustainable source of raw materials. Some additional measures for controlling pollution from brick manufacturing units in Assam under these rules include:

- i. The approach road within the site of brick kiln area should be pucca / stabilized with brick bats etc.
- ii. Brick kilns should use crushed coal for better burning efficiency.

- iii. Bricks should be laid in such a staggered manner for firing to entrap maximum particulate matter (PM) at the starting place itself.
- iv. Adequate pollution control measures like gravity chamber, water sprayers etc should be installed and operated at strategic locations of the brick unit.
- v. Permanent or fixed stack (chimney) should be installed at the brick kiln and the minimum the height of chimney /stack should be 30 meters.
- vi. For controlling dust, smoking and pollution the every brick unit should install water sprayers.
- vii. The approach road to site of brick kiln (including the storage site if it is at different place) from the nearest public road which is generally used for the transportation of raw materials and final products must be paved or hard surfaced.
- viii. Active haul roads inside the brick unit should be adequately wetted with water (preferably recycled and treated waste water) to reduce dust.
- ix. Exhausts of trucks for transportation of materials within the site should be directed upward.
- x. Brick kilns should provide wheel cleaning facilities for delivery trucks for the removal of mud.

6. Implementation of Various Measures for Controlling of Pollution in the Brick Kilns of Palasbari Revenue Circle:

Brick kilns of Palasbari Revenue Circle require substantial amounts of water for their production processes, which are typically sourced within the kiln premises to ensure uninterrupted operations throughout the season. Most units rely on water pump systems to meet their needs. So, there is no scarcity of water in the brick units in this area. The use of water is not subject to regulation or monitoring by local government authorities. Notably, three brick kilns in the area are located within 500 meters of the Brahmaputra River. The discharge of wastewater from these kilns, which contains high levels of suspended solids, contributes to river pollution and poses potential health risks to nearby communities.

The study found that brick kilns in the Palasbari Revenue Circle were established on land officially certified by the Circle

Officer of the Revenue Department, and the required “No Objection Certificates” were obtained from the respective Gaon Panchayats. However, field observations revealed that internal access roads within most kiln premises are neither paved nor stabilized with brick bats. Although all units use crushed coal as fuel and have installed fixed chimneys ranging from 80 to 100 feet in height in accordance with Pollution Control Board guidelines. Only one kiln has adopted measures such as water sprayer to control dust and emissions. Furthermore, approach roads of five brick kilns for transportation raw materials and final product are not hard surfaced. The frequent movement of heavy trucks carrying coal, soil, and bricks has also led to the deterioration of village roads. Additionally, there is a noticeable lack of greenery and tree plantation around the kiln sites.

The Assam Pollution Control Board, Guwahati has laid down specific guidelines regarding the location of brick kilns in the state. According to these norms, kilns should be established at a minimum distance of 500 meters from residential areas with a population exceeding 150 people or more than 20 houses, whether kutchra or pucca. They must also maintain at least a 500-meter aerial distance from public facilities such as schools, hospitals, and other institutions. However, In Palasbari Revenue Circle, it is observed that three brick kilns are situated hardly 400 m away from a Government LP School and five brick kilns are located directly in one village.

7. Sustainable Strategies and Policy Measures for Promoting Sustainable Development in Brick Kiln Industries

- All brick kilns in the Palasbari Revenue Circle continue to depend on conventional production techniques that require high fuel consumption and generate considerable air pollution, thereby contributing to environmental degradation. The adoption of more environmentally friendly technologies can significantly reduce these impacts. It is therefore important for the government to mandate the use of improved methods such as Vertical Shaft Brick Kilns (VSBK) and zig-zag kilns instead of traditional Bull Trench Kilns. These modern technologies are more fuel-efficient, ensure better combustion, and reduce heat loss during the firing process. Their adoption would not only lower pollution levels but also improve the quality of bricks produced.

- Adopting cleaner and alternative fuels, along with better insulation and efficient heat recovery systems, can significantly reduce energy use in brick production. Sustainable approaches also involve utilizing alternative raw materials such as fly ash, stone dust, rice husk, and other industrial by-products, which help limit the excessive removal of fertile soil.
- The government should enforce strict regulations to prevent the conversion of fertile agricultural land into brick kiln sites and ensure that such activities are limited only to areas unsuitable for cultivation.
- Brick production requires considerable amounts of water during molding processes. Implementing water recycling systems, rainwater harvesting, and proper wastewater management can help minimize water wastage and prevent contamination of local water resources
- To promote awareness about environmental impacts and sustainable production techniques Government should arrange different orientation and training programme from time to time.
- Financial incentives, subsidies, and tax benefits can encourage kiln owners to adopt cleaner technologies. These incentives help small-scale operators transition to sustainable production systems.
- There is a need for strict enforcement of environmental policies governing brick kilns, including clearly defined emission limits, effective pollution control strategies, and compulsory environmental clearance before their establishment or operation.

8. Conclusion

The study highlights that brick kiln industries contribute significantly to local economic development and help meet the increasing demand for construction materials. However, their reliance on traditional production techniques leads to considerable environmental damage, including air pollution, high coal consumption, and the depletion of fertile topsoil. These impacts not only degrade environmental quality but also pose serious threats to public health and agricultural productivity in nearby areas. Top of FormBottom of FormThe findings of the

study indicate that the lack of modern technology, inadequate regulatory enforcement, and limited awareness among kiln owners are major factors contributing to unsustainable production practices. Therefore, adopting cleaner and energy-efficient technologies, improving fuel efficiency, and promoting the use of alternative materials like fly ash bricks are essential steps toward reducing environmental impacts. In addition, strengthening environmental regulations, ensuring regular monitoring, and providing training and financial incentives to kiln owners can help encourage the adoption of sustainable practices. Through coordinated efforts from government agencies, kiln owners, and local communities, it is possible to minimize environmental degradation while maintaining the economic benefits generated by the brick kiln industry.

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