Journal of AgriSearch, 8 (4): 299-304
An Open Access International Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v8i04.7744

Effects of Brick Kilns Emissions on Land, Water, Agriculture Production, Socio-economic and Livelihood Status: A Review

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ABSTRACT
Rapid growth in population leads to urbanization resulting in considerable land use, land covers changes, and creates a sequence of environmental and food security problems. Due to speedy urbanization the agricultural lands has been converted into no-agricultural activity such as brick production. Brick kilns required larger areas for brick production and it removes agriculturally productive topsoil rich in clay, soil organic matter content and others important soil nutrient that is viable for agricultural growth. In addition to the removal of fertile top soil, brick kilns making process also emits harmful gases into the atmosphere. This harmful gaseous emission from brick kilns impacts the available natural resources and livelihood nearby it. Its emission results in decreased land and plant productivity, lowered ground water levels, and particularly leads to air pollution. It was found that neighbouring areas of brick kilns has low organic matter content and soil nutrients, and high soil electrical conductivity and low pH. It also changes the chemical and biological characteristics of soil and water. A change in physical, chemical and biological parameters of soil and water leads to reduce cultivated areas, and finally reduces agricultural production and productivity. It also directly impacts the food production system and could threaten the livelihood of present and future generations by degrading agricultural soil and consequently also eroding the economic basis of farmers.

KEYWORDS
Brick kilns, Physicochemical properties, land and water productivity, crop production

ARTICLE INFO

Received on	:	07/10/2021
Accepted on	:	27/11/2021
Published online	:	31/12/2021

INTRODUCTION

Brick kilns are also known as chimney. The brick making industry is gaining popularity in many developing countries mainly in South Asia. Globally, Asia alone produces 1300 billion bricks, which accounts for 86.67% of the world's brick production (ILO, 2017). India is the second largest brick producer in the world after China (approximately 200 billion bricks every year), which alone contributes 13.33% of total global brick production. In India, the per capita agricultural land availability has declined from 0.48 ha in 1951 to 0.14 ha in 2013 and may be 0.08 ha by 2035. Presently, 0.7 Mha of agricultural land is under brick kilns that produce approximately 250 billion bricks annually (Nath *et al*, 2018). Brick kilns (chimney) are the third biggest industrial consumer of coal in India (Seelam, 2016). Gangetic plains have one of the world's largest fertile alluvial soils, which produce around 65% of total brick production in India (Magazine Down to Earth, 2015). Annually around 600 million tonnes of clay soil are used for making of bricks, which damages topsoil, especially at riverbanks (NBM, 2019). Industrial sector of the country which contributes around 15% of all black carbon emissions, out of the total contribution around 9% through brick kilns (Mazumdar *et al*, 2018). In brick making technique clay and organic matter rich agriculturally productive topsoil is used. In addition to the removal of the fertile topsoil and accelerated degradation by other processes, this technique also emits CO_2 and other harmful gases into the atmosphere. Soil is the basic raw material for bricks and has the second largest share of the used materials with 46% and 1196.24kg/t (Table 1). The brick kilns operation over the years covers not only the neighbouring area of agricultural lands and vegetations with brick dust, but also changes the physicochemical properties and habitats of nearby soil by destroying soil nutrient and fertility (Islam *et al*, 2015). With a rise in urban population, it will continue to grow and create problems for agricultural production and farmer's livelihood in India. Considering the above issues, present study was conducted to analyses the impact of brick kilns emission on land, water, agriculture production, socio-economic and livelihood status in India.

Effect of Brick kilns emissions on natural resources

Effect on land characteristics

In Brick kilns top soils are generally used for brick formation. This process depletes the quality and quantity of the essential soil nutrient such as nitrogen, phosphorus and potassium, boron and zinc, which leads to soil fertility degradation and enhanced soil and water loss from its surroundings areas. It also disturbs the land topography, land use land cover (LULC), soil quality and biological activity near the surroundings areas of kilns. Brick kilns converts land in different forms such as plain into undulating, cultivated into

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Table 1: Material Consumption of Bricks production

Raw material	Consumption (Kg/tonne)	Consumption (%)
Water	1218.82	46.8
Minerals (Soil)	1196.24	46.0
Minerals (Sand)	94.12	3.6
Biomass (Rice Husk)	42.33	1.6
Fossil fuel (Coal)	46.69	1.7
Salt	3.75	0.1
Others (including diesel and petrol)	0.43	0.03

Source: Dominik (2015)

uncultivated, fertile into non-fertile and non-polluted into polluted areas. Generally, topsoil's up to 1.5 m or more depth of soils is used for the manufacturing the bricks. Topsoil mainly contains organic matter and other nutrients which is essential for sustainable agriculture. Brick kiln areas generate huge amount of dust that cause environmental degradation and soil texture disruption leading to land degradation, which affect agricultural production. Hossain *et al* (2019) reported that cultivable areas are decreasing by 0.73 - 1% annually in Bangladesh by the increasing the number of brick kilns and also have detrimental effects on degradation of lands, water and forest, topsoil fertility, land and water productivity, and deterioration of environmental quality. Bisht and Neupane (2015) reported that the land characteristics such as quality, LULC, topography etc. varied directly proportional to the distance from the brick kilns: that is, quality of soil increased with increasing distance from the kilns. Generally, 50-100 m distance from brick kilns soils is affected and is not suitable for cultivation without remedial measures (Ismail *et al*, 2012). The brick kilns are causing hydrologic problems such as lowering of the water level, decrease in water absorptivity and water holding capacity of land in brick kilns areas resulting lowering of groundwater table, poor groundwater recharge and increasing in losses of water such as surface runoff and evaporation (Table 2). Deeper soil removal (more than 0.3 m) resulted in a drastic loss of soil fertility and the land becoming agriculturally unproductive (Biswas *et al*, 2018).

Groundwater depletion

Haack and Khatiwada (2007) reported decrease in groundwater level to below 20 m from around 1-2 m below ground level in brick-producing area in Kathmandu valley, Nepal.

Land topography

Extraction of soil for bricks increases the possibility of landslides, disruption of irrigation systems and unusual surface elevations, which makes agricultural activity difficult.

Land use pattern

Brick kilns are mostly situated on fertile agricultural land, as brick manufacturers need silty clay loam to silty clay soils with good drainage conditions (Islam *et al*, 2015). The urbanization and the demand of brick manufacturing have resulted in change of the land used pattern from the good agricultural land turned into agriculturally unproductive lands.

Table 2: Soil texture of brick kilns sites

Location/sites	Water absorptivity (mg/L)	Sand (%)	Silt (%)	Clay (%)	Soil type
Nepal (Bisht and Neupane, 2015)	2.40-3.30	60-75	7-21	12-19	Silt loam
Bangladesh (Saha *et al*, 2021)	-	54-65	22-29	13-17	-

Effect on soil physico-chemical characteristics

Suwal (2018) reported that brick kilns alter the soil physico-chemical properties like EC, pH and soil nutrients of its surrounding areas. Deterioration of soil quality, nutrient content and water availability indicate that brick kiln is not suitable for good agricultural practices. Soil quality is degrading with increase in heavy metal content and decrease in nutrients like sulfate and nitrate. Loss of soil fertility along with accumulation of heavy metals like Pb, Cd, Cr and Ni severely affect the biodiversity and increase its concentrations in the food grains (Dey and Dey (2017) nd Adrees *et al* (2016) . Change in the concentration of heavy metals in the soil is affected by the changing in the soil texture i.e., sand, silt and clay proportion. Adrees *et al* (2016) found that brick kilns surrounding areas soils total concentrations of Ni, Pb, and Co were increased while organic matter content, Ca, Mg, and Na concentrations were lowest. After postharvest of crops from that areas total metal content, Ni, Pb, and Co concentrations slightly decreased. Haack and Khatiwada (2007) reported that brick kilns showed high concentration of nutrients, whereas in areas that had been used by brick kilns, these essential nutrients were very low. The physico-chemical characteristics of soil changes are shown in Table 3.

Water absorptivity and water holding capacity

Bisht and Neupane (2015) reported decreases in water absorptivity and water holding capacity near or surroundings areas of brick kilns.

Electrical Conductivity (ECe)

The Electrical Conductivity (EC) was almost double in the soil samples close to the brick field than the soil samples far from brick field. EC of the burnt soil increased twice of the unburnt soil as a result of the brick kiln operation.

Table 3: Physico-chemical characteristics of Brick kilns sites soil

Sites	pH	EC (μS/cm)	OM (%)	N (%)	K (meq/ 100 gm)	P (PPM)	S (PPM)	B (PPM)	Zn (PPM)	Cu (PPM)	OC (%)
Bangladesh (Hossain *et al*, 2019)	4.6-6.3	-	0.27-2.96	0.01-0.57	0.09-0.63	7.23-81.75	1.34-173.47	0.03-0.39	0.66-4.24	-	-
Bangladesh (Islam *et al*, 2015)	6.52-7.23	32.40-70.9	1.07-2.05	0.05-0.06	-	12.40-24.60	4.30-10.60		2.03-2.09	0.08-0.09	-
Nepal (Bisht and Neupane, 2015)	5.86-7.64	-	0.48-1.60	-	-	-	-	-	-	-	0.28-0.93
India	7-7.5		0.22-0.37		100-250	4.92-9.17					
Bangladesh (Saha *et al*, 2021)	6.18-8.48	165-453	0.34-3.21								

The significant increase in the EC value of the burnt soil was due to burning of salts/nutrients in the soils (Saha *et al*, 2021). High value of EC can toxic to plants and may prevent them from obtaining water from the soil.

pH

The brick kiln operation decreases the pH of surrounding soil, the study found the comparatively greater burnt soil pH than the unburnt soil. pH and nutrient content of soil inversely changes with distance from brick kiln. Saha *et al* (2021) concluded that the brick kiln surrounding areas have very low pH and organic matter content. Brick kiln decrease the soil pH (less than 7), leads to acidity of soil that increases the mobility of heavy metals like Pb, Cd, Cr, Cu, Hg, Ni, and Zn in the soils and also increases the availability of primary and secondary nutrients like N, P, K, ca, mg, and S in soil causes problems for normal growth of the plants and decrease soil microbial activity.

Organic Matter and Organic Carbon Content

The organic matter (OM) content in the soil sample close to the brick field was significantly lower than that of the far soil sample. OM content of the agricultural land around the brick field area was decreasing due to the burning of topsoil. It also changes the soil moisture and organic carbon (OC) content with distance i.e., near or its surrounding areas (Suwal 2018 and Rajonee and Uddin 2018), particle density was more or less in favourable condition for plant growth but bulk density and porosity indicates poor soil structure which is unfavourable for plant. The OM near to the brick kiln was found low due to low OC content. The OM content in soil gradually increased with distance away from the kiln. Organic Carbon content near to the brick kiln was low. It increases with increase in distance from kilns (Bisht and Neupane, 2015). Also, increase in heavy metal concentration significantly decreases the OC content of soil. The lower value of OM and OC in the soil is responsible for the lower cation exchange, water holding capacity and buffering properties of the soil (Saha *et al*, 2021). Lower value of N is due to loss of organic carbon which contains nitrogen and nitrogen fixing micro-organisms in soil.

Effect on environment and forest ecology

Brick kilns are considered as major contributor to climate change and a largest source of green house gas emissions including black carbon, carbon dioxide (CO_2), Sulfur oxides (SOx), Nitrogen oxides (NOx), carbon monoxide (CO), suspended particulate matters ($PM_{2.5}$), fluoride emissions and small amount of carcinogenic dioxins. Skinder *et al* (2014) reported that the average emission of gases per 1,000 bricks were 6.35 to 12.3 kg of CO, 0.52 to 5.9 kg of SO_2 and 0.64 to 1.4 kg of particulate matter. Brick kilns are the major contributor of black carbon which contributes about 20% of total black carbon emissions. A study conducted in Bangladesh reported that during dry season brick kilns contributes 30-50% $PM_{2.5}$ in the atmosphere. Thygerson and S (2016) reported that brick kilns contribute about 31% total suspended particles (TSP) in environmental air pollution. Acid deposits from SO_x and NOx emitted from the brick kilns negatively affect agricultural productivity (Hossain *et al*, 2019). Brick kilns are the largest source of greenhouse gases in Bangladesh emitting 87.5 lakhs tons of greenhouse gases per year. Large quantity of forest woods are used as fuel to burn the bricks, which leads to deforestation or forest degradation, with loss of environmental services (e.g. watershed protection) and biodiversity. Hossain *et al* (2019) also reported that forest woods were used in 18% of the brick kilns and generally, low quality wooden fuel used in it. The conventional brick manufactured by burning coal and ruining invaluable topsoil has a devastating effect on agricultural production, water availability and achieving sustainable development.

Effect on plants characteristics

The input material like minerals, water and biomass are the resources that are obtained from agricultural lands. While husk is a cheap and abundant by-product of the rice production, the depletion of water and soil, which together contributes 92.7% of the materials, has direct effects on the availability of these resources. While water is extracted from ponds or rivers, soil is mainly depleted from agricultural areas.

The emissions from brick kilns impact the soil, biodiversity and climatic parameters such as rainfall pattern, agriculture production and food security. It affects the plants in numerous ways such as banana is rotting, turning dry and leaves of banana trees are drying up and dying. The green coconuts are turning dry, the flowering of mango and litchis is also hampered by burning and drying away.

Hossain *et al* (2019) and Skinder *et al* (2014) reported that emissions from brick kilns affect the plant physiology, insect and pest infestation and hampered the bearing of fruit trees; damaged immature fruits & less fruiting in vegetables. The gas emitted from kilns reduces the chlorophylls contents of the plant species and dry or wet deposition of impurities on leaves. This is probably due to gas emitted from kilns enter into plant leaves through stomata and injury to leaves, damage cells such as burnt looking tips, causes squeezed appearance of fruits. Impurities (dry or wet) deposition like dust, fly ash, SO_2 & NO_2 on the leaves reduced interception of incident light and clogging of stomata (Hossain *et al*, 2019). Gaseous pollutants from kilns can cause leaf injury, stomatal conductance damage, premature senescence, decrease photosynthetic activity, disturb membrane permeability, reduce plant height, straw and grain yield, pushing away pollinating species that damage agricultural and farming production & productivity ((Adrees *et al*, 2016) . It reduced stomatal conductance, photosynthetic and transpiration rate was about 40%, 20-29% and 27-33%, respectively. Skinder *et al* (2014) reported that SO_2 showed negative effects in terms of foliar injury, physiological and biochemical alterations on vegetation and chlorophyll content decreasing with the increase in its concentration. It reduced chlorophyll, carotenoids and protein content was 30-40 %, 43-45 % and 25-27%, respectively. Soil modification with brick kiln dust was harmful to the nematode at all levels. The alkaline nature of brick kiln dust directly affects the maturity of plant, leading to less penetration to the roots and consequently delayed its development (Mazumdar *et al*, 2018).

Effect on agriculture production

Ahmad *et al* (2012) reported that hydrogen fluoride (HF) emission could reduce 40-60% of plant yields esp. apricot, plum and mango trees etc. Adrees *et al* (2016) found that gaseous pollutant from brick kilns decrease wheat plant height, straw yield and grain yield was 9-27%, 27-52% and 19-41 %, respectively. Haack and Khatiwada (2007) reported that brick manufacturing areas due to removal of the topsoil decrease in crop production is 50%. A study conducted in Bangladesh reported that topsoil removal for brick making reduce 40-80% in crop production and reduce rice and groundnut yields was 3% and 4%, respectively (Biswas *et al*, 2018). Reduction of crop yields in the year immediately following soil removal was 36% in the flood free area and 77% in the flood-prone area. A study conducted in Aligarh in Uttar Pradesh, India, reported that over a period of 20 years increased brick production decreased the cultivated area by 8.9% (Singh and Asgher, 2005). Nath *et al* (2018) reported that due to Brick kiln also impacts quality of the exposed subsoil, and may also reduce 60–90% agronomic yield. The effect of gas emission on crops production is shown in Table 4 .

Table 4: Brick kilns emission effect on crop production

Crop	Percentage reduction in yields	Source
Rice	10-62	Biswas *et al* (2018) Nath *et al* (2018)
Jute	74	Biswas *et al* (2018)
Wheat	20-53	Biswas *et al* (2018) Khan (2012)
Mustard	67-91	Biswas *et al* (2018) Nath *et al* (2018)
Lentil	88	Biswas *et al* (2018)
Vegetables (brinjal, cauliflower, cabbages, bottle gourd, bitter gourd and tomatoes)	99	Biswas *et al* (2018)
Potato	68	Nath *et al* (2018)

Effect on livelihood and socio-economic status

Firing of these bricks emits large amounts of carbon, soot, coal dust and other harmful gases, which contribute towards climate change and also impact the health of local people. Increasing number of brick making industry creating the environmental, social, economical and physical problems among the peoples' in society, also decreasing the quality and quantity of natural resources like soil, water and plant. At present time we have seen that the most of brick industry is installed nearby town or rural areas. Most of land areas near to villages are cultivable. According to the ENVIS Centre report in Punjab brick industries cause environmental pollution and land degradation besides decreasing herb density and causing nutrient disorders in plants/trees surrounding to it.

Skinder *et al* (2014) reported brick kiln emissions affect the biochemical parameters of vegetables crops like proteins, lipids, carotenoids and chlorophyll contents in Kashmir Valley. The imbalance in the biochemical parameters in vegetables will lead to serious consequences to both foods as well as health among the local population of the country. The peoples living in that area also said that they have got higher crop production in that area but after installations of brick kilns the crop productions decreased with time.

Heavy work load transportation, postural issues and repetitive movements are prevalent among workers and lead to acute and chronic musculoskeletal disorders. Dust from the brick-making sites spreads on the wind to nearby towns and villages, clogging the lungs of young and old and generating health problems the country is ill-equipped to handle.

The brick kilns emit toxic fumes containing suspended particulate matters rich in carbon particles and high concentration of carbon monoxides and oxides of sulphur (SOx) that are harmful to eye, lungs and throat. Due to excessive minerals contents that enter the hydrologic system, resulting in water pollution and increasing concerns about the quality of drinking water (Haack and Khatiwada, 2007). Khan and Shezadi (2021) reported that manpower/workers involved in brick making activities has poor economic condition, extremely bleak monthly income, which was around Rs. 600-900 per 1000 bricks per daily. The monthly income earned by the brick kiln worker is not sufficient to fulfil the expenditure of the whole month. Biswas *et al* (2018) reported that soil removal for brick making reduce 40-70% in income of farmers. Soil removal affected crop choice for cultivation reducing the nutritional value of crop yields and thus influencing food diversity which has adverse impacts on human health.

Remedial measures

Intervention of Agroforestry

Agroforestry practices such as the fertilizer tree (fast-growing nitrogen-fixing) systems have been known to improve soil organic content (SOC) build-up in depleted soils. Introduction and promotion of agroforestry i.e., *Piper betle* and plantations e.g., rubber, bamboo, etc. may significantly improve SOC stock in depleted soils in India. Through, bamboo plantation SOC may enhanced from almost 0 to 0.7 Mg ha^{-1} yr^{-1}

Technological intervention

Upgrade brick kiln technology from natural draft brick kilns to induced draft kilns. Vertical Shaft Brick Kiln (VSBK) process is an alternative, which is energy efficient method of firing. It produces better bricks and reduces pollution. According to Environmental Protection Agency adopting best practices in Bull Trench Kilns could result in energy savings of about one million tonnes of oil equivalent per year in India. As per the government policy (2013) requires shift to from fixed chimney kilns (FCK) to lower emission technologies including zig-zag (most popular option, a small-scale technology), VSBK, HHK or tunnel.

Policy measures

Every states of India have their own policy measures or recommendation for the establishment of brick kilns in their states jurisdiction (Table 5).

Table 5: Recommendation/criteria for establishment of brick kilns in an area

Organization/ Department/law& order	Guidelines	
	Recommended minimum distance for establishment of brick kilns	**Criteria/Applicability**
Ministry of Environment, Forest and Climate Change	800 metres or 0.8 km	from fruit orchards
	1000 m or 1 km	avoid clustering of kilns in an area
Uttar Pradesh brick kilns (Siting criteria for establishment) rules (2011)	not be less than 500 m or 0.5 km	avoid clustering of brick kilns in an area
	not be less than 800 m or 0.8 km	from sides of mango orchard/mixed fruits (mango and other) orchard (having at least 100 fruiting trees)/ joint nursery in each direction
Bihar Sate Pollution Control Board (2004)	400 m or 0.4 km	From an orchard (minimum area should not be less than one care)
	Prime agricultural land shall be avoided as far as practicable.	
Jammu and Kashmir brick kilns (regulation) Act (2010)	No brick kilns should be established on any land which is agricultural land and fit for cultivation of any agricultural produce.	
	Setting up of brick kilns should be allowed on the areas considered suitable for the purpose without any detrimental effect to the agricultural/ productive land.	
Land and Land Reforms Department, Government of West Bengal (2015)	No brick kilns shall be allowed to be set up on any land recorded as agricultural land/ orchard/ forest.	
	Within 300 m or 0.3 km	avoid clustering of kilns in an area
	Within radial distance 1600 m or 1.6 km	from mango orchards
Department of Environment, Govt. of Assam (2003)	not be less than 500 m or 0.5 km	avoid clustering of kilns in an area

CONCLUSIONS

Rapid population growth leads to urbanization of rural areas that threat to fertile agricultural lands and food security problems. Urbanization of areas changes available land scenarios, availability of natural resources, household shelter coveting from non-bricks to bricks foundation and socio-economic status of livelihood. Permanent foundation of living population leads to bricks demand from agricultural lands. Brick kilns emission directly and indirectly affects the land, water, crop, environment, livelihood and socio-economic status. Its' emission increases the gaseous concentration into the atmosphere and also into the natural resources components. Undesirable gaseous emission from kilns alter the phyiso-chemical characteristics of soil, soil moisture content, groundwater availability, and nutrient content of soil. The organic matter and nutrients contents were found very low while the soil pH and EC were relatively higher in brick kiln areas. It alters the crop yield, vary from crop to crop, region to region. To overcome the effect of emission on soil, crop and livelihood, remedial & policy measures, and technological interventions should be followed, that improves the changes occurring into available resources.

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Citation:
Jeet P, Singh AK, Sundaram PK, Upadhyaya A, Patel SK and Sarkar B. 2021. Effects of Brick Kilns Emissions on Land, Water, Agriculture Production, Socio-economic and Livelihood Status: A Review. *Journal of AgriSearch* **8**(4): 299-304