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IMPACT OF BRICK KILNING ON THE ENVIRONMENT: A STUDY ON KHULNA REGION OF BANGLADESH

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Abstract: This study identifies the patterns of energy consumption in brickfields as well as their impacts on the environment. An attempt has been made to estimate the emission of pollutants from brickfields to assess the impacts of the pollutants on human health. Finally, an attempt has been made to find out a solution to sink the CO_2 emitted by brickfields. Brickfields use coal, wood fuel, and crude oil mainly for burning bricks. Estimation reveals that in Khulna Region (KR) for the years 2003-2004, the coal requirement was 162 kton while the wood fuel required was 133 kton. Estimation also reveals that for KR the annual emission of the pollutants are about 738608 tons CO_2, 94 tons of CH_4, 13 tons of Nitrous Oxide (N_2O), 1989 tons of NO_x, 4264 tons of CO, 168 tons of Non-Methane Volatile Organic Carbon (NMVOC) and 15942 tons of SO_2. Estimation also shows that, for the present level of CO_2 emission in Bangladesh, annual afforestation requirement is about 1.4×10^9 m^2. The predicted concentration at 200 m downwind of brickfields is 3000 $\mu g/m^3$ for SO_2 and 300 $\mu g/m^3$ for NO_x and PM-10 during winter, while for summer the concentration is 1000 $\mu g/m^3$ and 125 $\mu g/m^3$ respectively. From the high concentration of these pollutants people face some health problems. About 30% of the brickfield workers suffer from dizziness while 60% feel fatigue and 75% suffer from headache. Those working for many years feel fatigue more than the new comers, 55% and 3% respectively.

Key words: Brick kilning, air pollution, environmental pollution, Khulna

Introduction

Brick is one of the main construction materials in Bangladesh. As a developing country, the urban areas of Bangladesh are expanding day by day. Hence, the need for bricks is increasing as the main construction material. Again, the input cost for brick manufacturing is not higher in comparison to other industrial sectors. The increasing demand of the bricks encourages entrepreneurs to invest in this sector. However, the manufacturing procedure is quite old. It has become a subject of environmental concern as brick burning process discharges huge quantity of pollutants to the atmosphere causing severe health and other damages because of the use of huge quantity of coal and wood fuel as energy.

There are about 6000 brickfields in Bangladesh (about 5000 registered and about 1000 unregistered), where two billion bricks are produced every year (BMA, 2003). Out of which, one billion and 375 million is burnt with wood, 400 million with coal and 225 million with natural gas. Every year total quantity of wood fuel available in Bangladesh is 204 million cft, out of which 52 million cft are burnt in brickfields (Miah and Alam, 2002). As a result, deforestation is a major problem for Bangladesh in the brick-manufacturing season. Wood fuels and fossil fuels, which are burnt in brickfields, are mainly responsible for the emissions of the trace and non-trace greenhouse gasses, such as CO_2, CH_4, CO, N_2O, NO_x, and NO (Anon, 1998). Therefore, brick industries are important sources of greenhouse gases as they use wood fuel, coal and fuel oil for high temperature brick burning. The quantification of green house gases is necessary to visualize the real situation of the green house effect and its consequences and ultimately to take effective measures to combat global warming.

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Brick-manufacturing season in Bangladesh is mainly the dry season, December to April. Therefore, dispersion of the pollutants emitted from brick kiln is a major concern. Pollutants emitted into the atmosphere undergo transport, dispersion, transformation and ultimate removal from the atmosphere. Wind speed, temperature, pressure, humidity, stability of the atmosphere, stack height everything effects the fate and dispersal of pollutants.

A few studies have been conducted on the impacts of brick kilns. Miah and Alam (2002) studied the deforestation and greenhouse gas emission caused by the brickfields in the Chittagong region. However, no study has been done on the brickfields of Khulna region. Attempt has been made to assess the overall impacts of brick kilns on the surrounding environment and human health in the Khulna Region (KR) of Bangladesh.

Materials and Methods

Study area: The Khulna region of Bangladesh (Khulna, Bagerhat and Shatkhira districts) was selected as the study area for assessing the impacts of pollution emitted from brick kiln on the environment. The study area is located between 21° 40/ and 23° North latitudes and 88° 53/ and 90° East longitudes. The average altitude of this area is less than two meters above the mean sea level.

Methods for estimation of CO_2, SOx , NOx , CH_4, PM , CO and Fl Emission from Brick Kiln:

Carbon Dioxide (CO_2): The estimation process can be divided in to six steps for CO_2 emissions from fuel consumption. (1) Estimate consumption of fuels by fuel / product type; (2) The fuel consumption was converted to common energy unit (TJ). This was done by multiplying the fuel consumption with heat values / net calorific values (Anon, 1996); (3) The heat energy figures are multiplied by fuel specific carbon emission factors to estimate net carbon content of each fuel type. Default carbon emission factors are taken from IPCC (Anon, 1996); (4) Net carbon emission is estimated by subtracting carbon stored from net carbon content. IPCC (Anon, 1996) manual is used to estimate carbon stored; (5) Actual carbon emission was estimated by multiplying net carbon emission with fraction of carbon oxidized. This step is aimed at correcting emission values for incomplete combustion; and, (6) The corrected value of oxidized carbon is then converted into CO_2 emission by multiplying by the stoichiometric factor (44/12); i.e., molecular / atomic ratio of CO_2 to carbon.

Methane (CH_4), Oxides of Nitrogen (NO_x), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Particulate Matter (PM), Fluoride (Fl) and Non-methane Volatile Organic Carbon (NMVOC): The general method for estimating these pollutants was described according to IPCC (1996) as:

Emissions = $\sum (EF_{abc} \times Activity_{abc})$ Where, EF = Emission Factor (Kg/TJ) *(Anon, 1996)*;

Activity = Energy Input (TJ); a = Fuel type, b = Sector activity, c = Technology type.

Method for estimating the ground level concentration of air pollutants: In the study, a computer based model for the dispersion of air pollutant from the point source was used (Anon, 2003). The model is provided by US EPA (Anon, 1999) and known as basic point source model. The model required emission rate, temperature, wind speed, dispersion coefficient and stack height as input. The model provides graphical representation of dispersion data of pollutants as output through which the concentration of pollutants can be obtained. The basic governing equation of the model can be expressed as:

$C_{x,y} = \frac{Q}{\pi u \sigma_Z \sigma_Y} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_Z}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_Y}\right)^2\right]$ Where, C = downwind concentration at ground level (g m^{-3}); Q = emission rate of pollutant (g s^{-1}); δ_y δ_z = Plume standard deviations (m); u = wind speed (m s^{-1}); H = effective stack height (m). The effective stack height is derived by adding the design stack height with the plume rise.

Method for estimating the deforestation rate due to collection of wood fuel: The study was conducted by directly interviewing the owners of brickfields and the staffs of BMA office. A general questionnaire was also used for the comments of local people and the brickfield owners as a measuring instrument. A field study was conducted in the randomly selected brickfields using a questionnaire over a period of three months from November 2003 to January 2004. A total of 75 enterprise, brickfields and BMA offices were selected for the study all over the country. Data or information was collected through either personal contact or

interviewing from different levels of staff of the respective enterprises or by investigating in the area. To avoid any misinformation, same questions were also asked to different levels of staff.

Method for estimating the rate of afforestation required to minimize CO_2 emitted from brick kilns: For estimating the afforestation required to minimize the CO_2 emitted from brickfields, a computer-based model, 'plant mod 2.1' (Thornley and Johnson, 1990), was used to calculate the net photosynthesis rate. The net photosynthesis rate presented by the model is in terms of CO_2 sink by the plants by photosynthesis. The input parameters required for the model are mean daily temperature (°C), day of year and the latitude and longitude of the location. The output of the model is a graphical representation of canopy net photosynthesis (g CO_2 m^{-2} d^{-1}) Vs mean daily irradiance (W m^{-2} PAR). From the output graph the net photosynthesis rate (g CO_2 m^{-2} d^{-1}) was calculated for the respective PAR of Bangladesh. The result represents the CO_2 sink by the plants.

Method for estimating the impacts of pollutants on human health: For identifying the health impacts, several villages around brickfields were surveyed. A general health questionnaire was the measuring instrument. The study also included the workers of brickfields. Here also the measuring instrument was a general health questionnaire for workers and a feeling fatigue scale. Exposure to pollution is a function of the air pollutant concentration in the breathing zone and the duration that a person experiences it. Mathematically, potential exposure is (E) was measured as Lioy (1990):

$$E = \int_{t1}^{t2} c(t)dt$$

Where, E = Potential Daily Exposure of an individual (mg h^{-1} m^{-3}); C(t) = Concentration of pollutants at time t (mg m^{-3}); t_1, t_2 = time range of exposure (h).

Results

Patterns of energy consumption in brickfields: Brickfields require a huge amount of different kinds of energy for producing the fired bricks. Conducting survey in the different brickfields of the Khulna and Shatkhira Districts the pattern of energy consumption was identified. The relative percentages of fuel that are being used for producing every $1x10^5$ bricks in Khulna region of Bangladesh are provided in Fig. 1, which shows that, of the total fuel used in the present days, about 63% of the fuel is coal in the registered brickfields. Wood fuel is used to fulfill the rest of the fuel required.

Deforestation rate due to collection of wood fuel: There are 280 brickfields in the Khulna region of Bangladesh (180 registered and 100 unregistered). On the other hand, there are approximately 6000 brickfields in Bangladesh. Field survey reveals that, about 18 tons of wood fuel is required for producing 10^5 bricks, along with coal. For using only wood fuel, the amount is 72 tons. However, for higher cost and government regulations only wood fuel is not used in maximum areas. The total wood fuel consumed in Khulna region of Bangladesh and whole Bangladesh for brick manufacturing during 2003-04 is provided in Table 1.

Table 1. Wood fuel consumed in Khulna region and Bangladesh for manufacturing of bricks during 2003-2004.

Types of brickfield		Number of brick fields [a]	Average production [a] (x 10^5)	Amount of wood fuel required [b] (t/10^5)	Wood fuel consumed (mt)	Deforested round-wood (m^3)
Khulna Region	Registered	180	30	18	97,200	4,33,512
	Unregistered	100	5	72	36,000	1,60,560
	Total	280			1,33,200	5,94,072
Bangladesh	Registered	5000	10	18	9,00,000	40,14,000
	Unregistered	1000	5	72	3,60,000	16,05,600
	Total	6000			12,60,000	56,19,600

Source: [a]BMA, Khulna office, 2003; [b]Field Survey, 2003

Pollutant emission during brick burning in 2003-2004: Brickfields are the major sources of green house gases and a huge amount of gases are emitted every year. The quantity of greenhouse gases emitted from brickfields was estimated from the total use of wood fuel, coal and crude oil for the whole of Bangladesh and for Khulna region (Khulna, Bagerhat and Shatkhira districts). This is provided in Table 2, which reveals that, in KR and for Bangladesh, coal burning highly contributes to the emission of SO_2 and NO_x, whereas wood fuel contributes to the huge emission of Carbon containing pollutants. The comparison of greenhouse gas emission for using coal and wood fuel for brick burning is provided in Fig. 2.

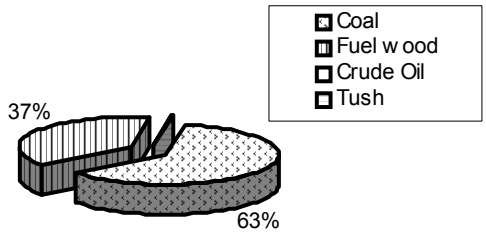

Fig. 1. Pattern of energy consumption in brickfields of Khulna region of Bangladesh (Source: Field survey, 2003-04)..

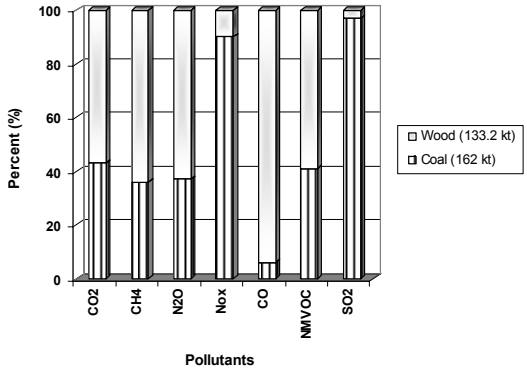

Fig. 2. Comparison of green house gas emissions: Using coal and wood fuel in Khulna region of Bangladesh during 2003-2004.

Table 2. Estimated total greenhouse gas emission from brick kiln for the whole of Bangladesh and for Khulna region in 2003-2004 for brick burning.

	Fuel Type	Fuel used (x 1000 ton)	Emissions (tons)						
			CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Khulna region	Coal	162	314341	34	4.75	1787	268	68	15390
	Wood	133.2	423517	60	8.0	199.80	3996	99.9	532.8
	Crude oil	0.245	750	0.02	0.01	2.07	0.103	0.0	19.60
	Total		738608	94.02	12.76	1988.87	4264.10	167.9	15942.4
Bangladesh	Coal	1800	3492681	377	52.7	19854.2	2976.2	753.5	171000
	Wood	1260	4006247	567	75.6	1890	37800	945	5040
	Crude oil	2.288	7003	0.2	0.06	19.29	0.964	0.001	183.04
	Total		7505931	944.2	128.36	21763.5	40777.2	1698.5	176223

Fig. 2 represents that wood fuel produced a lot of CO during burning of brickfields. CH_4, N_2O, CO_2 and NMVOC are also produced in higher amount from the use of wood fuel. These clearly suggest that wood fuel should not be used in brickfields to control greenhouse gases. The use of coal in brickfields, however, contributed the highest to total emission of SO_2, followed by NO_x, CO_2, NMVOC, CH_4, N_2O and CO in decreasing order.

***Concentration of air pollutants around the brickfields**:* For estimating the pollution concentration the ESS (Environmental Software and Services) point source model was used. Pollution levels in the vicinity of brick kiln in December 2003 and April 2004 were predicted in case of SO_2, NO_x, and PM-10. The results are summarized in Table 3.

Table 3. Pollution concentration, WHO standard versus concentration in brick kilns in Khulna region (KR) in 2003-2004.

Pollutant	WHO standard ($\mu g\ m^{-3}$)	Khulna region (KR) ($\mu g\ m^{-3}$)*	
		December	April
SO_2	100	3000	1000
NO_x	150	300	125
PM-10	150	300	125

* Calculated based on field survey data. Concentration around 400 m from the source and 24 hours average.

Table 3 reveals that, the concentration of SO_2 was 30 times higher in December 2003 and 10 times higher in April 2004 as compared to WHO standard. The concentration of NO_x and PM-10 in winter is 2 times higher than WHO standard but is slightly less than WHO standard in Summer. The concentration of SO_2 is always higher than the WHO standard, both in winter and summer days. This is because of the use of high sulfur containing coal being used in brick burning of Bangladesh.

Modeling study of afforestation required to minimize CO_2 emitted from brickfields: Brickfields produce a huge amount of CO_2, one of the major greenhouse gases. The plants are the major components of the ecosystem that can sink the CO_2, from the atmosphere. For estimating the afforestation required to minimize the CO_2 emitted from brickfields, a computer-based model was used to calculate the net photosynthesis rate.

Based on the model outputs, the net photosynthesis rates, i.e., the CO_2 sink rate by the plants for different months of brick burning season are provided in Table 4.

Table 4. Maximum CO_2 sink rate by the plants during brick burning season in Bangladesh.

Month of the season	Net Photosynthesis rate ($g\ CO_2\ m^{-2}\ d^{-1}$)
November	17
December	20
January	17
February	18
March	13
April	25
Average	18.33

Table 5. Daily exposure to major pollutants in the Khulna region of Bangladesh.

Pollutants	Average daily exposure concentration ($\mu g\ h^{-1}\ m^{-3}$)*	
	December	*April*
SO_2	72000	24000
NO_x	7200	3000
PM-10	7200	3000

* Calculated based on predicted pollution concentration.

Afforestation required: For the six months of brick burning season (i.e., November to April), the total CO_2 sink by the plants is 3299.4 $gCO_2\ m^{-2}$. Considering 'X' as the total CO_2 emission (g), the afforestation required is $\frac{X}{3299.4}$ m^2. For the present level of CO_2 emission, i.e., 7.5×10^{12} g, the afforestation required is 1.4×10^9 m^2, which is equivalent to 1.4×10^5 ha^{-1}.

People's perception on the impacts of brickfield pollution on human health: The people are generally not aware of the effect of the pollution they are facing and they are taking it normal. However, from field survey it was found that, the people at the downwind side are facing many problems than those at the upwind side of the brickfields. The people in the affected area by brickfields are in continuous exposure to SO_2 emitted from brick kiln. Thus, the prevalence of respiratory illness is quite higher among the people living near brickfields.

Exposure to pollution and health problems: The people around brickfields and the local inhabitants are continually exposed to high concentration of pollution all day long during the brick-burning season. Therefore, they are exposed 24 hours to this pollution concentration. Thus, local people are exposed to whatever is the pollution concentration in the area (Table 5).

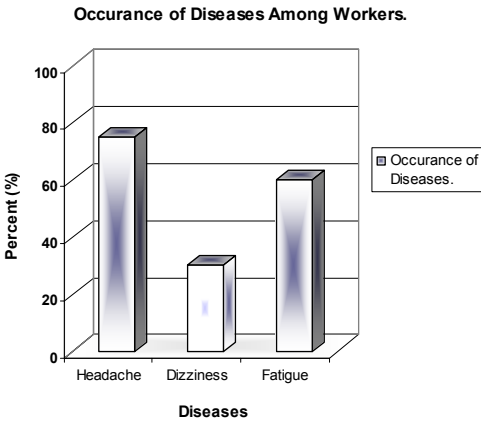

Fig. 3. Brickfield workers facing major problems and their occurrence (Field Survey, 2003-2004).

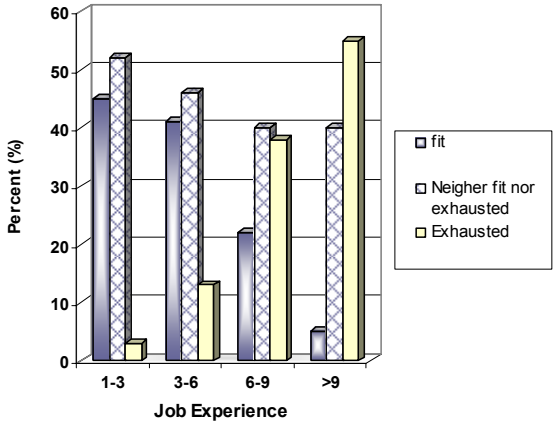

Fig. 4. Result of feeling fatigue scale depending on the job experience of workers.

***Impacts on workers*:** Conducting a field survey on the workers of brickfields it was found that most of the workers suffer from headache (75% of the workers responded) during the brick-manufacturing season. They also suffer from dizziness and fatigue and the percentage of the respondents are 30% and 60% respectively. Fig. 3 shows the result of the field survey graphically. The workers of brickfields claimed that they feel dizziness in the months of brick manufacturing. A survey was conducted on the workers to measure the percentage of the workers feeling fatigue during peak kilning season through establishing a feeling fatigue scale showing a line from exhaust to fit. The result is shown in Fig. 4. It is very evident from Fig. 4 that the feeling of fatigue progressively and steadily increased among workers, with the increase in years of working in the brickfields. The feeling of fatigue was about 3% among workers having 1-3 years work experience, about 12% among workers having 3-6 years working length, about 36% among workers having 6-9 years

work experience and about 54% workers having more than 9 years experience. In the survey, a significant number of workers were unable to express their feeling.

Impacts on localized people: The major problems the localized people face is due to the higher concentration of SO_2. Conducting a survey in the adjacent villages of brickfields in winter days it was found that people suffer with respiratory problems and eye irritation. About 40% of the respondents informed that they had major problem of eye irritation in the brick-burning season while 35% was confused about their exposure. About 25% people were sure that they had no eye irritation problem.

Discussion

Brick kilns are meeting the demand of urbanization and playing an important role in expanding structure in Bangladesh. But brick kilns are causing some environmental problems too. Brick kilns emit huge amount of CO_2, CH_4, N_2O, NO_x, CO, SO_2, PM, NMVOC and other pollutants. Concentration of pollutants in the downwind of brick kilns is very high. From the high concentration of these pollutants people face some health problems in the surrounding area of brick kilns. Brick industries are important sources of greenhouse gases. CO_2 is the most prominent from brick burning. It is considered to be a major gas contributing to global warming and climate change. SO_2 is another important pollutant emitted from brick kilns. It causes serious environmental problems. It is the major source for acid rain. SO_2 has also adverse effects on human health. Concentration of more than 0.01 g m^{-3} SO_2 can give rise to severe effects in the form of broncho constriction, chemical bronchitis and chemical tracheitis. Constrictions in the range 0.0026-0.0027 g (2600-2700 μg m^{-3}) give rise to immediate clinical symptoms with bronchospasm in asthmatics.

Proper way of burning and imposing laws and regulations and maintaining those strictly can reduce pollution level generated by brickfields. Improving technology may be the best recommendation in the context of reducing pollution level and environmental damage.

Conclusion

About 63% of the fuel used in the registered brickfields is coal. For brick burning a huge amount of green house gases and other pollutants are emitted into the atmosphere, as a result the people around the brickfields suffer from many diseases. Modification of existing laws and their enforcement could help in improving the situation. The law, however, should cover the technology, stack height, and fuel usage types. Public awareness should be grown in this regard, as they are the victims of the pollution. Shifting towards suitable technology should be the main emphasis to reduce this hazard. The use of pollution free concrete blocks would be suggested in constructing buildings.

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