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ENVIRONMENTAL ASSESSMENT OF BRICK KILN IN KHULNA, BANGLADESH: A CASE STUDY

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ABSTRACT

Brick manufacturing is a primary industry of infrastructure development almost all over the world and the kilns using old technologies are highly polluting in Bangladesh. This study investigates the amount of brick kiln emission of a coal-based Brick Field in Pother Bazar, Khulna. This study revealed that emissions from brick kilns were found for PM_{10} (9.4 ton/yr), SO_2 (8.1 ton/yr), CO (5.4 ton/yr), NO_x(3.0 ton/yr) and VOC_5 such as Acetone (4.59 kg/yr), Benzene (1.96 kg/yr), Xylene (1.195 kg/yr), Phenol (0.236 kg/yr), Toluene (1.688kg/yr). The comparison between emissions due to the use of different fuel types was shown and Coal-fired kilns emit more amount of PM_{10}, SO_2 and NO_x but less amount of CO than Natural gas and Sawdust fired kilns. This assessment is significant for developing emission estimation method, emission reporting, and emission database for the brick kiln in Bangladesh which will be an invaluable tool for policy formulation.

Key words: *brick kiln, air pollution, emission factor, fixed chimney bull's trench kiln.*

INTRODUCTION

Brick is a popular construction material for thousands of years. At present, the demand of bricks is soaring, especially in the developing country like Bangladesh, where infrastructure development projects are the top priority. Brick making is a significant sector in Bangladesh, contributing about one percent to the country's gross domestic product (GDP) (BUET, 2007) and generating employment for about one million people. Due to the unavailability of stone aggregate, brick is the main building material for the country's construction industry, which grew an average of about 5.6 per cent per year (Arifur, 2006). The current population of the country is assessed at around 149 million (BBS, 2011). A large portion of this huge populace is migrating to the urban areas for better living condition. Owing to this rapid urbanization, a sharp rise of 5.6 percent per year has been noticed for the construction industry. This trend eventually directed the brick sector to increase annually at a projected 2 - 3 percent over the next decade for housing construction and commercial sector developments (WB, 2010). Though, the brick manufacturers in Bangladesh is therefore expanding in production, a good number of these producers are not formally recognized as industry and not advancing technologically (MOI, 2010). The kilns and technology remained unchanged for long times back and still consumes energy inefficiently. Biomass, mainly firewood and rice husk, are the main energy sources for the brick firing (Alam, 2009). Despite the importance of brick making, the vast majority of kilns use outdated, energy-intensive technologies that are highly polluting the environment. It leads to harmful impacts on health, agricultural yields and global warming. The New technologies, such as the Vertical Shaft Brick Kiln (VSBK) and the Hybrid Hoffmann Kiln (HHK), are substantially cleaner than the Fixed Chimney Kiln (FCK) currently used. These improved technologies consume less energy and emit lower levels of pollutants and greenhouse gases (GHGs) (BUET, 2007; Heirli and Maithel, 2008). The existing brick kilns are the number one cause for fine particulate pollution in Bangladesh and its total greenhouse gas (GHG) emission is estimated to be 15.67 million tons of carbon dioxide (CO_2) equivalent (tCO_2e) per annum. Global warming is an issue that calls for a global response. In addition, Bangladesh is one of the most climate change vulnerable countries. In Bangladesh, 92% of the 4,880 (Butler et al., 2004) brickfields are highly polluting Fixed Chimney Kilns (FCKs) because of a combination of low capital cost requirement and high investment return. However, these kinds of kiln use more coal/wooded fuel, which emits more carbon. Brick making significantly contributes to local air pollution including emission of various harmful gases such as Sulphur Oxides (SO_x), Nitrogen Oxides (NO_x), Carbon dioxide (CO_2) and Suspended Particulate Matter (SPM) and PM_{10} (Iqbal, 2007). About half of Bangladesh's

bricks are baked with the use of coal, which is now considered the source of some 20 per cent of global greenhouse-gas emissions (Enters, 2000).The main reason for poor emission from brick kilns is the poor quality of coal and uses of biomass mainly firewood. The main pollutants which are emitted from the brickfields are particulate matter (PM), some hazardous gases like CO_2, CO, NO_x, NO and SO_2. The PM concentration appears to be low but it is expected to have long term massive impact on global environments as well as on human health. The particulate matter consists of dust, smoke, fumes, and fly ash. Ahmed and Hussain (2007) studied the pollutant load within the cluster region of brick kilns in Bangladesh for SO_2 and particulate matter. It was found that particulate matter was a major pollutant in that region. The specific objectives of the study are- 1.to assess the physical overview of Pother Bazar brick kiln Khulna city, 2.to estimate the air pollutants from the fuel (coal) of the brick kiln, 3. to determine the chemical composition of coal sample, 4.to analyze the emission of air pollutants due to coal fuel type and compare it with other fuel types (wood, sawdust) used in brick kiln.

METHODOLOGY

Study Area

This study is to be based mostly on information that has been collected from field survey and some laboratory test. Field survey was carried out on the selected brick kiln in Khulna city. This kiln location is shown in Figure 1. The kiln is situated near the country side of Khulna city in Pother Bazar beside the Jessore- Khulna highway. It is about 15 km away from the main city. This area is an industrial area where various numbers of industries are located so that I selected this site for the study. This brick field named Khan Jahan Ali Brick Ltd. is a Fixed Chimney Bull's Trench Kiln where about 25000 brick is produced daily and carried about six month in a year.

Figure 1 The selected brick field for the study (source: Google Earth)

Physical Overview & Questionnaires Surve

The layout of the brick kiln was collected and the detail survey was done. The process of making a brick and how it is burnt was observed. Some pictorial view is also collected from the brick field for further studies. Reconnaissance survey was done. Questionnaires survey was also done to gather knowledge about the existing emission control system of the brick kiln and environmental condition of the surrounding. Physical condition of the labor of the kiln was also observed.

Proximate Analysis

The brick kiln is a Bull's trench kiln using coal as fuel. From the proximate analysis the moisture content (MC) and volatile matter (VOC) were determined for different temperature shown in Figure-4.1. The quantities are determined by measuring the mass loss of coal sample undergoes when heated to 110°C for moisture content and 550°C for the volatile matter under the nitrogen atmosphere following equation-1.

$$MC/VOC\ (\%) = (W_2-W_3) / (W_2-W_1) \text{..... (1)}$$

Where,
W_1 = Pot / Dish weight; W_2 = Pot + Material weight in normal temperature
W_3 = Pot + Material weight after burn

Chemical Analysis of Coal Sample

The chemical and organic content in coal sample was estimated by bio-available analysis using spectrophotometer. The main substances of coal which has a great impact on environment are Fe, S (as SO_4), N (as NO_3) and As. For determining Fe, S (as SO_4), N (as NO_3) and As, first we prepared the sample by mixing 300 ml water with 50 gm of coal. Then I took 10 mL sample water and mixed Ferrover Iron Reagent for Fe and the reaction time was 3 minutes, Sulfaver-4 and 5 minutes reaction time for Sulfur, Nitrover^R and 5 minutes reaction time for Nitrate, and for Arsenic we took 3 sample and mixed Sulfonic acid and Zinc.

Emission Estimation

Emission factor method was followed from Emission Estimation Technique Manual for Brick, Ceramics & Clay Product Manufacturing which is under National Pollutant inventory (NPI) of Australia 1998. In this Manual, it relates the quantity of substances emitted from a source to some common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources and are usually expressed as the weight of a substance emitted multiplied by the unit weight, volume, distance, or duration of the activity emitting the substance. Emission factors developed from measurements for a specific brick kiln or process may sometimes be used to estimate emissions at other sites. Should a company operate several units of similar size and configuration and if emissions were measured from one brick kiln or kiln process, an emission factor could be developed and applied to similar kilns and processes. As previously mentioned, it is advisable to have the emission factor reviewed and approved by your local environmental authority prior to its use for NPI estimations. Air pollutants like PM_{10}, CO, SO_2, NO_x and VOCs from brick kiln can be estimated directly by using emission factors with the following equation 2.

$$E = A \times T \times EF \times [1 - (ER/100)] \text{..... (2)}$$

Where, E = emissions;
A = activity rate (usually production rate);
T = time (or another variable);
EF = uncontrolled emission factor; and
ER = overall emission reduction efficiency, %

RESULTS & DISCUSSION

Proximate Analysis

From the proximate analysis the moisture content (MC) and volatile matter (VOC) were determined for different temperature shown in Figure 2. In figure 2 the 110^0C shows the percent value of moisture content (MC) and 550^0C showing the percent value of volatile organic compound (VOC).

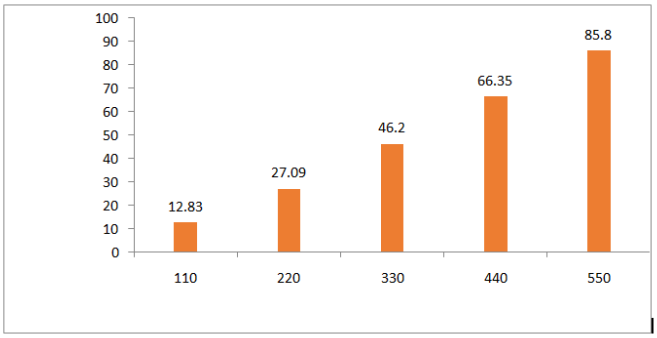

Figure 2 Proximate analysis data

Chemical Analysis

The chemical and organic content in coal sample was estimated by bio-available analysis. The main substances of coal which has a great impact on environment are Fe, SO_4, NO_3 and As. In Table 1 the amount (kg/ton) of Fe, SO_4, NO_X and As consist in coal sample are as follows. The chemical compositions of coal sample Fe (12.3 gm/ton), S (as SO_4) (2.8 kg/ton), N (as NO_3) (1.8 gm/ton) and As (0.00 gm/ton).

Table 1 Bio-available Analysis of coal sample

Coal Sample	NO_3 (gm/ton)	As (kg/ton)	Fe (gm/ton)	SO_4 (kg/ton)

S-1	1.79	ND	12.4	2.73
S-2	1.80	ND	12.2	2.85
S-3	1.81	ND	12.3	2.82
Avg	1.80	ND	12.3	2.80

Emission from Brick Kiln

From emission factor method the emission of air pollutant from the brick kiln in Pother Bazar, Khulna was calculated and the result is shown in the following table. The brick field is a uncontrolled coal fired so as the respective factor was used. The emission of the PM_{10} is the maximum of all the air pollutant and it possesses 36.34% of the total emission. Sulphur is one of the major pollutants that emits from the brick kiln that have a 31.15% of total emission. The other two pollutants CO and NO_x have 20.76% and 11.68% respectively of the total emission. The emission per 1000 bricks production has also been calculated and it has been shown in the Table 2, Table 3 and Table 4.

Table 2 Emission from Brick Field in Pother Bazar, Khulna

Substance	Emission (ton/yr)	Emission per 1000 bricks (kg)
PM_{10}	9.45	3.78
SO_2	8.1	3.24
CO	5.4	2.16
NO_x	3.037	1.21

Table 3 Emission of VOC_s from Brick Kiln

VOC_s	Emission (ton/yr)	Emission per 1000 bricks (kg)
Acetone	4.59	1.84
Benzene	1.96	0.78
Carbon Disulphide	0.016	$6.4x10^{-3}$
Chloroform	$6.75x10^{-4}$	$2.\ 7x10^{-3}$
Dibenzofuran	$2.43x10^{-3}$	$9.72x10^{-4}$
Ethyl benzene	0.142	0.057
Xylene	1.195	0.48
Phenol	0.236	0.094
Styrene	$6.75x10^{-4}$	$2.7x10^{-4}$
Tetrachloroethane	$6.75x10^{-4}$	$2.7x10^{-4}$
Toluene	1.688	0.67
Trichloroethane	$6.75x10^{-4}$	$2.7x10^{-4}$
Chloroethane	0.074	0.0296
Total VOC_s	9.91	3.964

Table 4 Emission of Other Material

Substance	Coal Fired Kiln (ton/yr)	Emission per 1000 bricks (kg)
Arsenic	0.878	0.35
Beryllium	0.108	0.043
Manganese	0.196	0.078
Mercury	0.648	0.26

COMPARISON OF EMISSION USING DIFFERENT FUEL TYPES

Emission of PM_{10}

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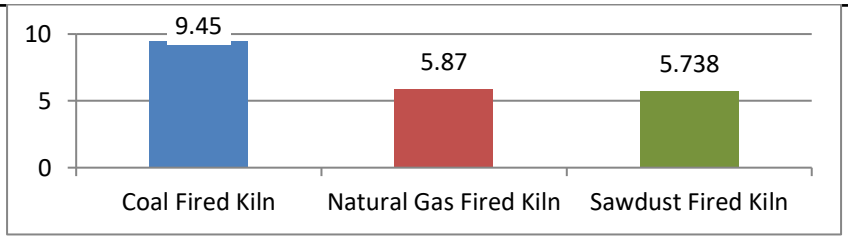

Figure 3 Comparison between Emission of PM_{10}(Ton/yr)

From this figure 3 it is visible that emission of PM_{10} in coal fired kiln is very higher than other kiln. In case of Natural Gas and Sawdust fired kiln its emission is quite same. As because coal emits lots of Black Carbon and other micro particle as the kiln use very fine coal, chance of emission of fine particle is very much less in Natural gas and Sawdust fired kiln. Emission of PM_{10} in Natural gas and Sawdust fired kiln are quite same having difference of 0.132 ton/yr but in coal fired kiln the variation is large.

Emission of SO_2

The following figure 4 shows that in Natural gas and Sawdust fired kiln there is a little difference in SO_2 emission and their difference is only 0.613 ton/yr. But in case of Coal fired kiln the deviation is very high and it emits a large amount of SO_2 than the other as the coal has a greater proportion of Sulphur. The difference is about 2.227 ton from Sawdust and 2.84 ton from Natural gas fired kiln. Coal possesses a rich amount of Sulphur which oxidized during combustion and produces a large amount of SO_2.

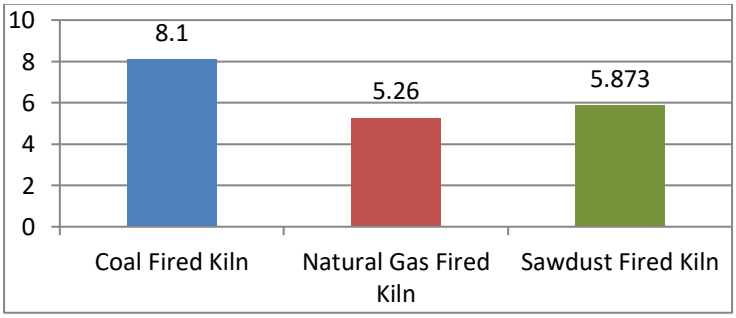

Figure 4 Comparison between Emission of SO_2 (Ton/yr)

Emission of CO

Combustion of this organic content produces a huge amount of carbon monoxide. Coal has other inorganic content also so a coal fired kiln emits less amount of CO than other. Meanwhile Sawdust and Natural gas fired kiln emits huge amount of CO. Figure 5 shows that the variation of emission of CO among the entire three kilns is large such as Sawdust fired kiln emits about 5.4 ton more CO than coal fired kiln and 2.7 ton more than Natural gas fired kiln. So here it has been seen that coal fired kiln emit less amount of CO than other kilns.

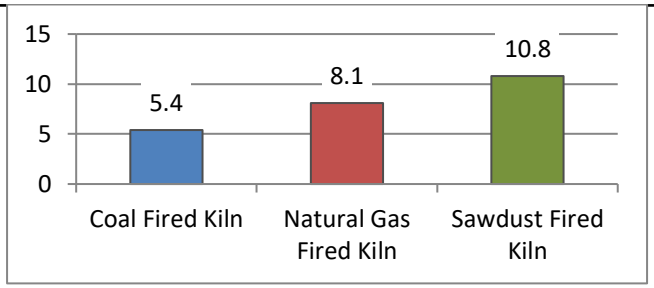

Figure 6 Comparison between Emission of CO (Ton/yr)

Emission of NO_x

Emission of NO_x fluctuates very less for various fuel. It is clearly visible in the following figure. All types of fuel generate about same amount of NOx. Coal fired kiln emits 3.037 ton every year where Natural gas fired kiln and Sawdust fired kiln emit 2.362 and 2.498 ton/yr respectively. The difference of emission of NOx between coal fired and Natural gas fired kiln is 0.675 ton and the difference with Sawdust fired kiln is 0.539 ton. The variation between Natural gas and Sawdust are very low and its value is only 0.136 ton every year.

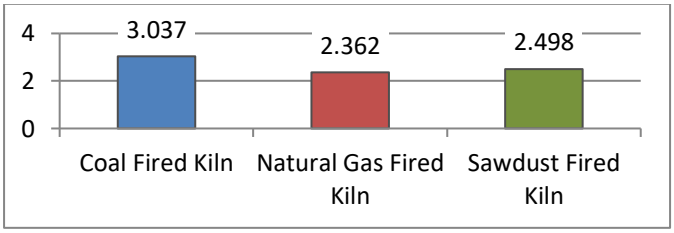

Figure 7 Comparison between Emission of NO_x (Ton/yr)

Emission of VOCs

Emission of VOCs is almost same for all type of fuel excluding some particle such as Acetone, Benzene, toluene and Chlorine. In every case it has been shown that Natural gas fired kiln emits the maximum amount of VOCs from the following figure it can be seen that emission of Acetone, Benzene, toluene and Chlorine are larger and maximum emission occurred in case of Natural gas fired kiln. The variation of emission of Acetone is large among the three types of kiln. Natural gas fired kiln emits 6.88 ton and 8.837 ton more Acetone than Coal fired and Sawdust fired respectively. The variation of Benzene emission is also very high. If the total amount of VOCs emission is observed it can be seen that the Natural gas fired kiln emits 46.05 kg more than Coal fired kiln and 47.64 kg more than Sawdust fired kiln. If the total mission of Natural gas fired kiln is considered then it can be observed that the VOCs emission in Natural gas fired kiln possess 0.25% of its total emission. Where Coal fired kiln emits only 0.038%. The difference of emission of VOCs between Coal fired and Sawdust fired are very low.

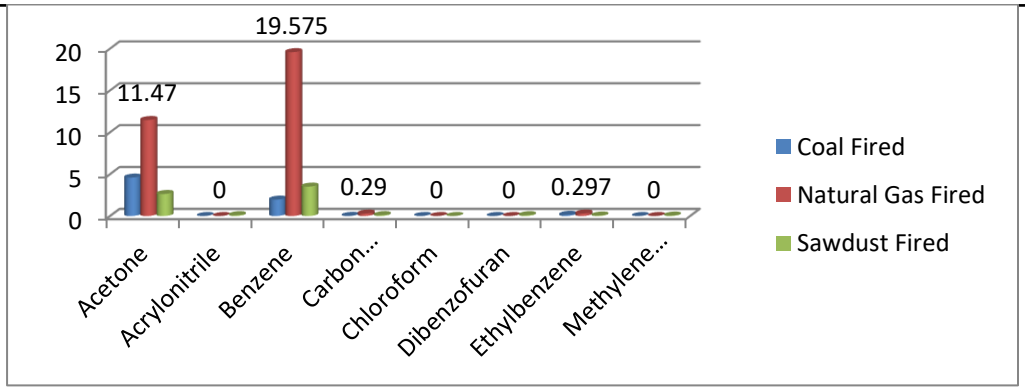

Figure 8 Comparison Between Emission of VOC$_s$(kg/yr)

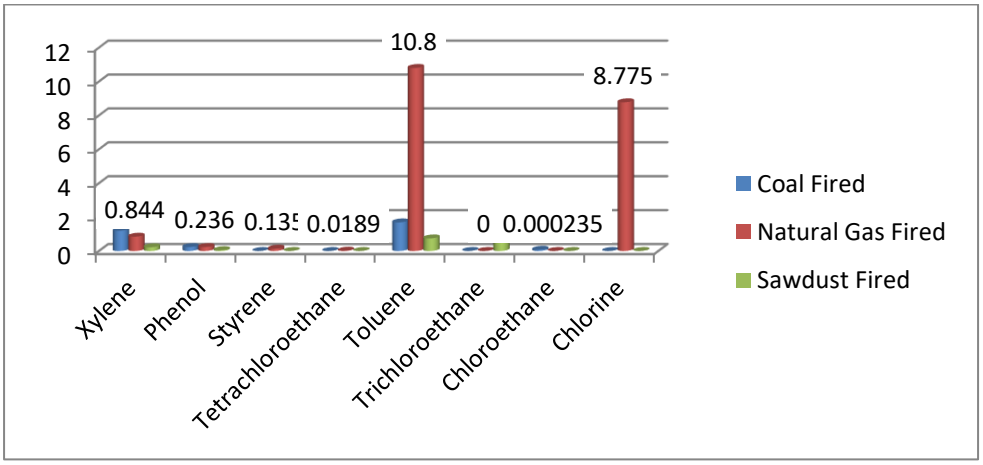

Figure 9 Comparison Between Emission of VOC$_s$(kg/yr)

Emission of Other Particle

This Figure 10 shows the other types of emission like Arsenic, Beryllium, Manganese and Mercury. Arsenic is emitted much by Coal fired kiln but the maximum amount of manganese is emitted by Natural gas fired kiln. The emission of Arsenic, Beryllium, and Mercury are same for Natural gas fired and Sawdust fired kiln. Where the emission of Manganese in Sawdust fired kiln differs a lot from other emission it emits about 87.75 kg of Manganese every year. It possesses 0.35% of total emission in a Sawdust fired kiln.

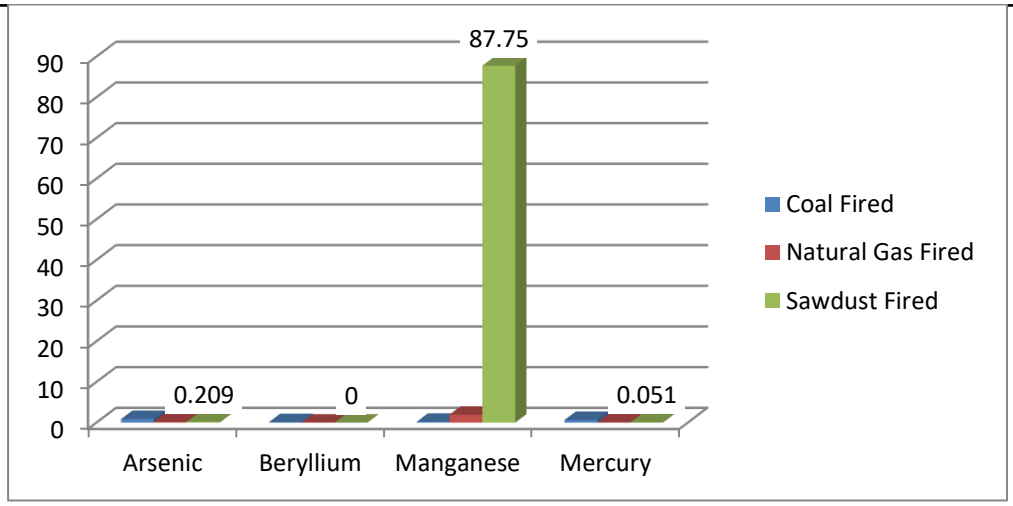

Figure 10 Comparison between Other Emission (kg/yr)

From the above discussion it has been understood that emission from Coal fired kiln is larger than other kiln though in Bangladesh most of the brick kiln uses coal for the combustion process. Because of cost efficiency, availability and flexibility, coal is suitable which can provide a huge amount of heat in the burning chamber. Moreover in case of Natural gas and Sawdust, generation of required temperature for proper burning is very difficult. In our study area the brick kiln also uses coal as fuel.

CONCLUSIONS

Air pollution due to brick kiln emission is an increasing environmental concern in Bangladesh. This study was visualized the current state of air pollution from brick kiln , major sources of air pollutant, and suggests future strategies to reduce the air pollution in Jessore city. The findings of the study can be concluded as:

- The proportion of chemical content of the coal sample was determined and the organic component and the molecular absorption were found.
- Estimation of the present air pollutant emission from brick kiln in Jessore city was done. The emission from brick kiln were found for PM_{10} (9.45 tone/yr), SO_2 (8.1 tone/yr), CO (5.4 tone/yr), NO_x (3.037 tone/yr) and various type of VOCs as respectively. The emission for 1000 brick production has also been found.
- The comparison between emission due to use of different fuel types was shown where it is visible that Coal fired kiln emits more amount of PM_{10}, SO_2 and NO_x but less amount of CO than Natural gas and Sawdust fired kiln. Maximum amount of CO emission occurred at sawdust fire kiln. Whereas VOCs are emitted mostly by natural gas fired kiln.
- The brick kiln which is used for this study is an uncontrolled coal fired kiln. The mission of smoke from the burning chamber is forced to release through the chimney and the heat is reserved. But there is no use of any kind of filtering process to reduce the emission of air pollutant.
  From various VOCs maximum emission is occurred for Acetone, Benzene, Toluene and Chlorine. In every case maximum emission of this organic content are emitted by Natural gas fired kiln. For other emission like Arsenic, Beryllium, Manganese and Mercury the maximum emission of Manganese are caused by Natural gas fired kiln. The results that were obtained from this study are expected to help developing future policies and safety programs to control the brick kiln emission in the Jessore city and rural areas. Following can be maintained for air pollution from brick kiln emission:
- A possible initiative is required to develop emission standard for other cities and compare that with this study. Once the emission standard is developed for brick kiln, air pollution can easily be estimated.
- This emission assessment is significant for developing emission estimation techniques, emission reporting, and emission database for the brick kiln in Bangladesh.
- An immediate decision is needed to be taken by Government of Bangladesh to Promote cleaner production in this industry requires extensive understanding of work with brick making technology changes.

- It is essential to follow proper technique or methodology while estimating emission factor for different pollutants.

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