Brick Manufacturing Practice in Bangladesh: A Review of Energy Efficacy and Air Pollution Scenarios[1]

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Abstract: Building structures and major construction works are booming in the urban areas of Bangladesh to keep up the rapid urbanization rate. Brick is an essential construction material for its building industries. To meet the need of construction, brickfields are growing sporadically here and there at the fringe zones and within the urban regions. Eventually, brickfields are producing major environmental pollutants. This paper highlights existing technologies of brick manufacturing as well as their emission which exceeds the tolerable limit and puts a threat to the environment. Treatise is also portrayed regarding techniques which could help minimizing the drawback of existing brick kiln technologies. Vertical Shaft Brick kiln might be an alternative solution for the small investors in Bangladesh which is energy efficient and can minimize the air pollution to achieve a sustainable environment.

Keywords: Brick kilns, environment, energy consumption, pollution, green house gas emission.

1. 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. The current population of the country is assessed at around 149 million (BBS, 2011). A large portion of this huge populace are 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 an 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). Brick making is traditionally a cottage industry which produces bricks for local consumption; though its technological development is inadequate.

Current technologies for brick production such as clamps, high draught kilns and bull's trench kilns consume large quantities of fuel such as coal, firewood and other biomass (Begum et al, 2010). In Bangladesh, about 4,500 brick kilns are in operation, producing about 9 billion bricks per year (Gomes and Hossain, 2003). Of the 4,500 kilns, more than 4,000 are of the Bull's trench kiln (BTK) type. The BTK employs an extremely crude technology to fire bricks. There are also about 400 fixed chimney kilns, 15 zig zag kilns, 25 Hoffman kilns and 5 modern tunnel-type kilns currently in operation in the country. Hoffman kiln uses natural gas and the other three types of kiln use low-grade coal and firewood as fuel (Begum et al, 2011).

The devastating effect of the pollution caused by the huge amount of emission from the brick industry has attracted the attention of the regulatory agencies, like the Department of Environment (DoE) in Bangladesh. Bangladesh Government first promulgated the 'Brickfield Law

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(Regulation)’ in 1989 that prohibits the use of biomass in Brickfield. This law was amended in 1992. But the total condition of the Brickfields remained largely unchanged. The study shows a huge number of unregistered brickfield are producing brick without having any license which are mainly responsible for violation of the present regulation (Iqbal, 2004).

Till now, the greater part of the brick factories are operating Fixed Chimney Kiln (FCK) technology with coal as the key fuel as it is more economical than the alternatives (Hossain, 2008). FCKs are not energy efficient and consequently pollutants are being emitted by a greater rate. To ease the emissions from brick field industries, the Government is working to propose alterations in FCK technology and newer technologies such as Zig-Zag and Hybrid Hoffman kilns, which are more energy efficient (Hossain, 2008). The problem with the brick industry can be found in all South Asian and several Southeast Asian countries as well as China. The problems related to brick manufacturing using the BTK and other polluting and inefficient technologies have been examined, but often no solution to the problem has been offered. (AIT, 2002a; AIT, 2002b; AIT, 2002c). Well-known energy research institutes such as The Energy and Resources Institute (TERI) and Development Alternatives (DA), both of New Delhi, India, have been trying to popularize VSBKs (Maithel et al, 2003) but with limited success.

This goal of the study is to identify the principal technical approaches and some barriers, to assess alternative strategies for pollution control and to explore broad implications for large or small-scale brick kilns in developing countries like Bangladesh. A more complete knowledge of raw materials and their properties, better control of firing, improve kiln designs; exhaust air quality enhancement and more advanced mechanization will result in the development of a progressive, modern industry.

2 Major pollutants emission from brick fields

Brick making is an energy intensive process (Croitoru and Sarraf, 2010, Narasimha and Nagesha, 2013). Brickfields are the important contributors of the emission of greenhouse gases in Bangladesh as they burn huge amounts of coal and wood fuel. As a result, rate of deforestation increases in the brick making season of 6 months. If the wood fuel burning is stopped in Brickfields, the Bangladesh Atomic Energy Commission accounts that 2.1 petajoules of energy (Which is equivalent to the energy produced by $2.1 \times 2312 \times 100$ tons of refined fossil oil) will be saved.

Burning of wood fuel except bamboo is illegal (GOB, 1989) but till now a huge amount of wood fuel is being used. After the Government regulation in Brickfields, the major fuel used now for brick manufacturing is coal. The conventional practice of firing clay bricks in rural country clamps and BTKs (Bull Trench Kiln) consume huge quantities of fuel in terms of coal, firewood and other biomass fuels such as old tires, tainted sawdust, discarded motor oil , plastic and household garbage, dung cakes and agricultural residue. In Bangladesh, the brick industries consume several million tons of coal biomass fuels; kilns are notorious as highly polluting establishments, affecting not only just flora and fauna but also posing threats to human health. Higher energy costs and the inability of the industry to meet the environmental standards have raised serious concerns about the survival and well being of the industry.

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.

3 Hazards from pollutants

Huge amounts of hazardous materials are discharged from the brick manufacturing industry, which would have great impacts on the environment as well as on human health as discussed below.

3.1 Effects of particulates

Particulate is one of the major pollutants emitted from brickfields. Two types of particulate, settlable and suspended are produced, both are harmful for human health and the surrounding environment (Croitoru and Sarraf, 2010).

3.2 Effects on human health

At high concentration suspended particulate matter poses health hazards to humans, particularly those susceptible to respiratory illness (WHO, 1999). As indicated in Table 1, the nature and extent of the ill effects that may be linked to suspended particulates depend upon the concentration of particulates, the presence of other atmospheric contaminants (notably sulfur oxides) and the length of exposure.

Table 1 Particulate matter effects on health (WHO, 1999)

Concentration $\mu g/m^3$	Accompanied by	Exposure Time	Effects
750	715 $\mu g/m^3$ SO_2	24-h average	Considerable increase in illness
300	630 $\mu g/m^3$ SO_2	24-h average	Acute worsening of chronic bronchitis patients
200	250 $\mu g/m^3$ SO_2	24-h average	Increase absence of industrial workers
100-130	120 $\mu g/m^3$ SO_2	Annual mean	Children likely to experience increased incidence of respiratory diseases
100	Sulfation rate above 30 $mg/cm^2/mo$	Annual geometric mean	Increased death rate for those over 50 likely
80-100	Sulfation rate above 30 $mg/cm^2/mo$	2-yr geometric mean	Increased death rate for those 50 to 69 yrs

3.3 Effects on plants and animals

Dry brick kiln dust appears to cause little damage if deposited on a leaf surface, yet in the presence of moisture; such dust imparts damage and consequential growth inhibition to plant tissues. Dust coating of leaves reduces photosynthesis and the increased plugging of stomata reduces plant growth. Animals who eat plants coated with particulates may suffer from some ill effects (Jan et al, 2013, Fatima, 2011).

3.4 Effects on materials

Particulate matter can damage materials by soiling clothing and textiles, corroding metals (especially at relative humilities above 75%),eroding building surfaces, and discoloring and destroying painted surfaces. For example, at particulate matter concentrations ranging from 130 to 180 $\mu g/m^3$ and in the presence of SO_2 and moisture, corrosion of steel and zinc panels can be three to four times greater than in areas close to background particulate levels (60 $\mu g/m^3$).

3.5 Effects of Sulfur Oxides

SO_2 emission is one of the concerns of environmental pollution by the brick industry (US EPA, 1986). It may have some significant impact on the environment and human health. SO_2 is one of the principal pollutants, which gets emitted from brick industry. Sulfuric acid (H_2SO_4), Sulfur dioxide (SO_2) and sulfate salts tend to irritate the mucous membrane of the respiratory track and foster the development of chronic respiratory diseases, particularly bronchitis, pulmonary emphysema and asthma. Individuals who suffer from chronic respiratory diseases may experience coughing and a difficulty in breathing when the SO_2 concentration rises from 0.1 to 0.2 ppm. Also SO_2 is the primary component of acid deposition and damages the ecosystem both directly and indirectly. The WHO guideline for SO_2 emission is 0.9 ppm at sampling time of 10 minutes. Table 2 shows the effects of SO_2 on humans.

Table 2 Effects of SO_2 on humans (WHO, 1999)

Concentration ppm	Exposure Time	Effects
0-0.6		No detectable response
0.15-0.25	1-4d	Cardio respiratory response
1.0-2.0	3-10min	Cardio respiratory response in healthy subjects
1.0-5.0		Detectable responses, tightness in chest
5.0	1 h	Choking and increased lung resistance to air flow
10.0	1 h	Severe distress, some nose bleeding
Greater than 20		Digestive tract affected, also eye irritation
400-500		Dangerous for short period of time

3.6 Effects of oxides of nitrogen (NOx)

There are different types of oxides of nitrogen, such as N_2O, NO, N_2O_3, NO_2, N_2O_5 out of these oxides NO_2 emissions is too high in the brickfield and it has quite high impact on the environment as well as on human health (IPCC, 1996;US EPA, 1999).

The main component of NOx emitted from brickfield to the atmosphere is NO and NO_2. NO is a relatively inert gas and only moderately toxic. Although, NO, like CO, can combine with hemoglobin to reduce the oxygen carrying capacity of the blood. NO concentrations are generally less than 1.22 (1ppm) is the ambient air and thus is not considered as a health hazard. This irritates the alveoli of the lungs; the response of the human respiratory system to short term exposure to nitrogen dioxide. Other ill effects include heart tightness, barring of eyes, and headaches. People with asthma and bronchitis are particularly vulnerable to these effects. Recurrent exposure to high concentration of NO is more damaging that constant exposure to low level concentration. The WHO guideline for ambient concentration is 0.2 ppm (400) at a sampling time of 1 hour.

3.7 Effects of CO

CO at present ambient levels has little if any effect on property, vegetation or materials. At high concentrations, it can seriously affect human aerobic metabolism, owing to its high affinity for hemoglobin, the component of the blood responsible for transport of oxygen. CO reacts with the hemoglobin (Hb) of blood to form carboxyhemoglobin (COHb) thus reducing the capability of blood to carry oxygen. Hence, more blood need to be pumped to deliver the same amount of oxygen, resulting in strain on the heart. This is fatal when inhaled at very high concentrations, and heart disease patients, pregnant women, infants, senior citizens and those especially susceptible to respiratory problems may exhibit symptoms of poisoning at a relatively lower concentration. The WHO guideline for ambient CO concentration is 87 ppm (100) at a sampling time of 15 minutes.

4 Brick kiln technology

Brick manufacturing process in Bangladesh is being carried out in a very primitive way. Still date traditional process is applied in Bangladesh. These age-old methods of manufacturing brick are leading to environmental degradation. The demands for bricks continue to rise, as the population increases and people aspire to having better standards for housing. To supply this growing demand as well as to reduce fuel consumption and air pollution it is necessary to develop new technologies and process of brick manufacturing. In the technological aspects the existing kiln technology should be studied in details.

5 Classification of brick kiln

Brick kilns can be classified into four main categories, on the basis of how they are operated:

- Intermittent or periodic Kiln: intermittent or periodic kiln that consists of a single firing chamber. The intermittent kilns are loaded with green bricks, which is fired and allowed to cool before unloading, in preparation of next loading and firing. These types of kilns are capable of firing only one loading of brick at a time.
- Semi continuous kiln: Semi continuous kiln, where two or more intermittent kilns are interconnected by flues and dampers, to allow the heat from cooling bricks in one kiln to dry and pre-heat the bricks in another. The kilns are alternated being unloaded once the heat from the cooling bricks had been used to dry and pre-heat the bricks in the second kilns, that is then fired up to top temperature.
- Continuous kiln: In the continuous kilns, the firing zone moves through the kilns without stopping. Green bricks are loaded in front of firing zone and fired bricks are removed behind it. These kilns run day and night, with the fire never going out except for seasonal or maintenance stoppages.
- Tunnel kiln: In Tunnel kilns, the bricks are placed on trolleys and moved through the hottest part of the kiln at a predetermined rate. This is a form of continuous kiln, but with a stationary rather than moving firing zone.
- Kilns can be further subdivided into three main classes, based on how they actually work.
- Up-draught kilns: Up-draught kilns where the heat travels naturally by convection, from the area of combustion up through the bricks.
- Down–draught Kiln: Down–draught Kiln, where the heat combustion is drawn down through the bricks by use of a chimney or forced draught system.

- Horizontal/cross draught kilns: Horizontal/cross draught kilns, where the heat of combustion is drawn sideways thought the bricks by the use of a chimney or forced draught system.

6 Kiln technology

Different types of kilns in the technological point of view are used in brick manufacturing in Bangladesh. Most of them, which are technically not sound enough to produce brick without polluting the environment. Recently, the researchers have done some technical improvement in the brick kilns.

6.1 Clamps

This is a very old aged method of manufacturing bricks. The clamp is the most basic type of kiln since no permanent kiln structure is built (Aziz 1981). The bricks are stacked in alternate layers to reach the desired height, gradually tapering towards the top. The base of the clamp is rectangular. The top surface is covered with earth to prevent the escape of heat. The biomass (fuel wood) is used on clamp as fuel.

6.2 Bull's Trench Kiln (BTK)

This type of kiln (Fig. 1), which is generally used in Bangladesh, has some technological drawback. Now a days, a few countries are trying to improve this technology and going to implement in the modern sector.

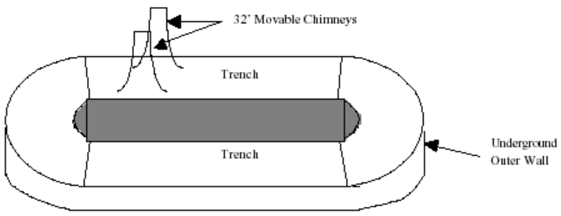

Figure 1 Schematic diagram of a BTK

The main deficiencies of existing Bull's Trench Kiln are noted below (Aziz, 1981):

- Improper kiln construction leads to excessive air leakage from the kiln system thus increasing the losses.
- Small size chimney leads to excessive flue gas temperature to give effective draught.
- Heat loss from the side and top do not allow attainment of full firing temperature and thus leads to deterioration in quality of fired goods.
- Very high loss due to repeated heating of the kiln system because of high thermal mass.

6.3 Hoffman Kiln

The Hoffman kiln has fixed roof, which enables bricks to be fired throughout the year. The inside roof of the kiln is arched and has a firebrick lining on the inside surface. The thick walls of the kiln and good insulation minimize heat loss to the surroundings. The bricks are fired from the top by introducing the fuel (natural gas) into the combustion zone through pipe-type burners. The burners are shifted forward from section to section as the fire progresses fired bricks are unloaded at the back while green bricks are stacked in front of the firing zone. The flue gas has been conveyed towards the chimney through a network of channels just below the kiln. Fire is controlled without the aid of any instrument or controllers by merely adjusting the gas flow rate and the opening and closing of dampers located at selected points in the flue gas network. Controlling the fire is the trickiest part of the whole operation.

6.4 Vertical Shaft Brick Kiln (VSBK)

An energy efficient and sustainable alternative to traditional brick kilns is Vertical Shaft Brick Kiln (Fig. 2). This technology which is originated in China, is all set to emerge as a viable alternative for small-scale brick manufacturing in developing countries.

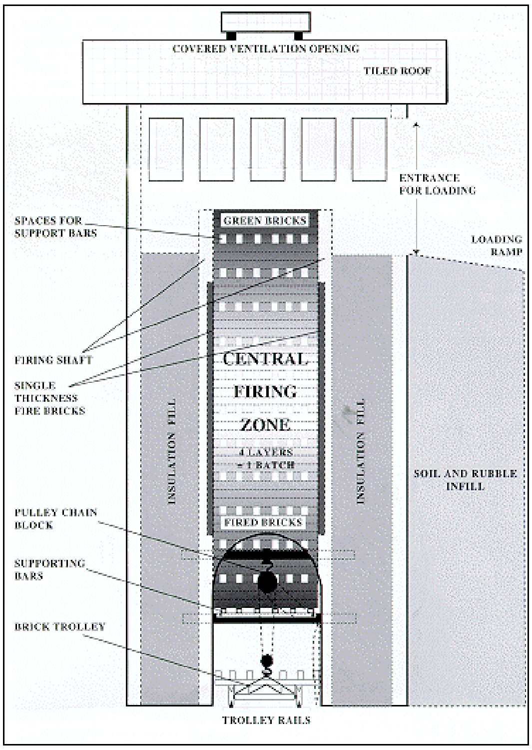

Figure 2 Schematic diagram of a VSBK (reference may be needed if it has been taken from other source)

Advantages of VSBK Technology are discussed below:

- Highly energy efficient methods for firing bricks: VSBK technology results in an energy saving of about 50% compared to clams and 20 to 30% compared to BTKs (TERI, 2009).
- Compact kiln: The kiln is very compact. For the same production capacity VSBK needs about 20 to 30% of land required by BTKs (TERI, 2009).
- The construction cost: Thought slightly higher compared to that of a BTK, is still reasonably low.
- Weatherproof: It can be operated during the monsoon because, unlike other traditional kilns, VSBK has a roof, which provides protection from rain allowing year-round operations. Other brick kilns can operate only 5 to 6 months in a year.
- Suitable for internal fuel bricks. The kiln is highly suitable for use where fuel is added internally into the brick. In some countries agricultural residue like rice husks and fuels like coal dust are mixed with clay before molding. This allows the use of inferior quality fuel and in general, results in the reduction of the production cost. VSBK, because of being fast-firing characteristics, are particularly suited for firing bricks containing internal fuel.
- Modularity in construction and flexibility in production are important attributes of the technology. Additional shafts (production capacity of 2,000 to 5,000 bricks per day) can be easily added/operated as per the demand for bricks.

7 Comparative Energy Consumption in Different Brick Kiln

Specific fuel consumption in brick manufacturing is an important factor for the environmentally friendly brick industry. This depends upon the type of raw clay available for making bricks, kiln used for firing, the fuel used and the operation practice in place. Energy consumption of the different brick kilns is compared in Table 3.

In Fig.3, energy consumption is compared amongst different brick kiln technologies which was carried by the Tata Energy Research Institute (TERI). The study depicted that the VSBK kiln consumed the lowest specific energy utilization.

Table 3 Energy consumption in different types of Kiln

Process	Technologies	Specific Energy Consumption (Gcal/'000 nos. Brick)		Status
		Coal	Biomass	
Firing	Bull's Trench Kiln (Movable Chimney)	1.08	-	Existing
	Bull's Trench Kiln (Fixed Chimney)	0.86	-	Existing
	Clamps	-	1.35	Existing
	Vertical Shaft Brick Kiln	0.57	-	New
	High Draught Kiln	0.72	-	Existing

Source: Development Alternatives, 1995

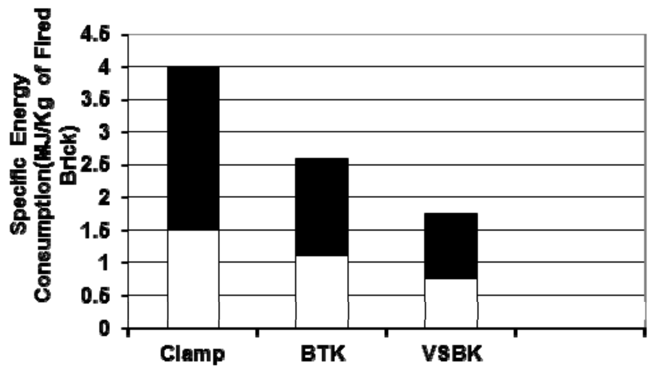

Figure 3 Comparison of specific energy consumption

8 Emission co-efficient

Brich industry consumes not only a lot of coal but also a lot of biomass energy in the form of agricultural residue. However, since the biomass is considered to be carbon neutral, no CO_2 emissions are estimated from its combustion. Their individual carbon emissions rates are low while their carbon content is high indicating an inefficient production. Efficiency improvement measures for these units would offer benefits for higher profit margins, better compliance with pollution control norms and in turn could improve the local environment. In Table 4, a comparative data on CO_2 reduction potential are demonstrated amongst the three types of brick kiln.

9 Particulate Matter

The major pollutant emitted from brick field is the Suspended Particulate Matter (SPM). Increasing the stack height of the kiln, the pollution concentration can be reduced around the area of Brickfields. It is estimated that, while for 60 ft stack height the concentration of pollutants exceed the WHO standard (100 for SO_2, 150 for PM and NOx), (WHO, 1999) increasing the stack height to 120 ft, the concentration can be well controlled.

Table 4 CO_2 reduction potential of the Hoffman kiln and VSBK (Gomes and Hossain, 2003)

	BTK	Hoffman	VSBK
Fuel	Coal	Natural Gas	Coal
Fuel consumption per brick	0.28 Kg	0.1632 m^3	0.17 kg
Total fuel	28 t	16320 m^3	20 t
Total energy consumption	586 GJ	571 GJ	419 GJ
CO_2 emission	55.4 t	32.0t	39.6 t
CO_2 emission reduction compared to BTK (%)	-	42	28.5

Basis : 100,000 bricks produced

Conversion Factors: Heating value of coal = 20.93 GJ/t ; Heating value of natural gas = 35 MJ/m^3

CO_2 emissions of coal = 94.6 t CO_2/TJ ; CO_2 emission of natural gas = 56.1 t CO_2/TJ

10 Scope of improvement: perspective of Bangladesh

Brick kilns are one of the major sources of emission in Bangladesh. There is wide scope to improve the traditional brick manufacturing process of Bangladesh. The major issues in environmental improvement involve the increasing of the combustion efficiency of existing kilns, and upgrading kilns to newer and more efficient process design, upgrading the design of the chimney so that it emits less hazardous pollutants and the overall process technology upgrading. Process technology upgrades are usually capital intensive. Combustion efficiency improvement can be achieved with relatively lower costs in many kilns. Promoting cleaner production in this industry requires extensive understanding of work with brick making technology changes. Several low cost ways to increase efficiency and to reduce waste and pollution in brick making are described below.

Stack fuel around bricks to facilitate preheating:

Solid fuel is mixed with the bricks throughout the kiln, either as sawdust mixed into the brick mass or as fuel channels in different levels of the kiln. By doing this, a combustion zone can be generated in the kiln that gradually moves upwards, using the residual heat in the lower, already burnt bricks for preheating of combustion air. The residual heat in the flue gases is used for drying and preheating of the higher levels of crude bricks.

Improve brick drying before firing:

Extended drying time reduces fuel requirements. Even drying throughout brick stacks reduces defective firing of bricks.

Improve airflow control:

Stopping air leaks and controlling the kiln opening size allows better control of airflow speed and direction to improve combustion.

Switch to propane or natural gas fuel:

If available and competitively priced, these fuels have significantly less emission and can increase production quality and speed.

New kiln design:

Vertical shaft brick kiln allows increased production rate and significantly decreased emissions through improved combustion airflow efficiency. Several kiln designs have also proven to be relatively low-cost and much more efficient than traditional ovens or kilns.

Some newly developed technologies may be introduced in Bangladesh. The Bull's Trench Kiln, which is common in Bangladesh, may improve this technology by taking some measures. Most of the technology consists of movable metallic chimney, which can be replaced by fixed chimney. A gravitational settling chamber may be designed and set up at the chimney to reduce suspended particulate in the flue gas passing through the chimney. The following steps may be adopted to take necessary measures to upgrade the existing technology.

- The traditional BTK technology could be upgraded by adding limestone scrubbers to reduce sulfur dioxide emissions and filters for entrained particulate removal. (Pembshaw and Smith, 2005).
- Mixing and pulverizing the fuel before combustion and adding insulation would also result in higher energy efficiency. Fuels such as natural gas and low sulfur coal could replace the current fuel mix of wood and poor quality coal.
- A properly designed chimney of 120 feet height (as per the requirement of the Department of Environment, Bangladesh) along with an integral gravitational setting chamber should be provided.
- To supplement the chimney, the flue ducts are to be designed to provide the least amount of resistance to the flue gases.
- Alternate building materials such as straw bales, block bricks, cement blocks and reprocessed waste could also be employed to reduce the demand for ceramic bricks.
- Properly designed chimney which provides required draught for combustion fuel and transfer from cooling zone to firing zone and then to pre-heating one.
- Gravitational settling chamber providing below the chimney which arrests SPM.
- Space for valves providing in flue lines, which will fulfill the requirements of factory acts.

11 Conclusion

Brick making is an energy intensive process. It should emphasize the need for energy conservation and pollution control in brick industries of Bangladesh. In this paper data for different types of fuel consumption and emitted pollutants from the Brickfields have been compared. Some of the technical options are discussed as an effective means of energy conservation and pollution control. However, existing technologies are not energy efficient. On the other hand, new technologies are not popular in Bangladesh and costly in terms of initial investment. Following notes cannot be made from this study:

- If these existing approaches (e.g. Clamp, BTK etc.) are replaced overnight by the modern but expensive and complicated technology like Hoffman's kiln, fixed chimney kiln or Zigzag kiln, those traditional brick kiln owners would be wiped out and this incident will have a great impact to the national economy of Bangladesh. As a result, consumers will have to buy bricks at a higher rate which will create a negative impact on the rapid growth of the urbanization. Therefore, a transition should be created between the existing and proposed techniques.
- The government should come forward to establish a platform for stakeholder interaction (industry representatives, policy makers, researchers and financial institutions) to expedite the adoption of efficient kiln technologies and should offer incentive to the entrepreneurs of the new green approach.
- A feasible alternative for the small investors might be Vertical Shaft Brick Kiln (VSBK) method which consumes relatively smaller energy with lower initial investment and can be operated against the natural calamities like rain or flood.

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