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Health Impact Of Air Pollution On Dhaka City By Different Technologies Brick Kilns

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Abstract: The main source of air pollution in Dhaka City is emissions from brick kilns. This study assessed the main factors that affect the city's air pollution levels, as well as the contribution of the different types of brick kilns located in different zones in Dhaka. The significance of air pollution variable and the health impact were examined and policy analysis with respect to kiln type was done. The specific variables analyzed were PM_{10}, $PM_{2.5}$, SOx, NOx, NO_2, CO, and O_3; of these only PM_{10} and $PM_{2.5}$ exceeded the Bangladesh air quality standards and those prescribed under the World Health Organization air quality guidelines. The study found that vertical shaft brick kilns (VSBK) had the lowest PM_{10} and $PM_{2.5}$ emissions, whereas the zigzag types were the second lowest emitters. But in terms of SOx and CO emission, zigzag, gave the lowest values. For CO_2, the hybrid hoffman kiln (HHK) had the lowest emission. The PM_{10} and $PM_{2.5}$ data from the brick kilns were used in the health effect model and it was shown that zigzag kilns' emissions can be reduced by 60%; VSBK, by 83%; and HHK, by 57%. These results can be used to avoid harmful health effects and to determine the disability-adjusted life year, as well as save on health care cost.

Keywords: Dhaka City, Air Pollution, Brick Kilns, Health Impact

Introduction and Purpose

Dhaka, the capital city of Bangladesh, comprises the Dhaka City Corporation (DCC) and five adjacent municipal areas, Savar, Narayanganj, Gazipur, Keraniganj, and Tongi. The area of this mega city is 1,353 km^2, of which DCC occupies 276 km^2. The city is situated between 23° 42' and 23° 54' north latitude and 90° 20' and 90° 28' east longitude. Dhaka's population grows at an estimated rate of 4.2% per year, one of the highest among Asian cities [1]. The continuing growth reflects ongoing migration from the rural areas to the Dhaka urban region, which accounted for 60% of the city's growth in the 1960s and the 1970s. More recently, the city's population has also grown with the expansion of city boundaries, a process that added more than a million people to the city in the 1980s [1]. According to the Far Eastern Economic Review, Dhaka will become the home of 25 million people by the year 2025 [2]. In search of better job opportunities [3] and to gain access to urban amenities, rural people move to urban areas, and this trend has put a lot of pressure on the city's population growth. Concomitant with this migration pattern, the demand for different urban infrastructure has increased at an alarming rate, resulting in a very large demand for building materials such as bricks [4]. Dhaka has witnessed the fast growth of urban population in recent years. Air pollution in Dhaka City is reported to be pose a serious risk to public health. In the winter of 1996-97, air pollution in the city most severe, when lead in the air was reported to be higher than in any other place in the world [5]. Motor vehicles and brick kilns are the largest sources of particulate air pollution, including black carbon in Dhaka [6] [7]. Brick-making is important to the economy of Bangladesh as it contributes about 1% to the country's gross domestic product (GDP) [8] and generates employment for about one million people. Due to the unavailability of stone cumulative, brick is the main building material used by the country's construction industry; usage grew at an average rate of about 5.6% per year from 1995 to 2005. In spite of the economic importance of brick-making, the vast majority of kilns used is outdated and use energy-intensive technologies that are highly polluting [9]. As Dhaka is mostly dependent on bricks for infrastructure, the brick kiln manufacturers proliferated in the city to meet the demand for bricks. Additionally, a large number of brick kilns operating in the city further mushroomed to meet the increasing demand triggered by economic growth. Because of this pollution caused by the brick kilns increases day by day. The kilns are located in Dhaka's Keraniganj, Gazipur, Naraynganj, Savar, and Dhamrai, clusters. Air pollution has become one of the serious environmental concerns in urban areas, bringing about adverse health effects that have been associated with ambient fine particles [10] [11]. Due to enhanced human activities that increase emissions, atmospheric pollution in urban areas has become a major issue in many developing countries. The rate of increase in pollutant concentrations in these places is higher than that in the cities of the developed countries [12]. In general, the study aimed to do analyze the factors that cause air pollution in Dhaka, Bangladesh. Specifically, the study aimed to i) identify and determine the significance of the existing air pollution condition in Dhaka, Bangladesh; ii) quantify total emissions from brick kilns that cause air pollution in Dhaka; and iii) assess the health impacts of emissions from existing brick kilns.

Design and Methods

Since April 2002, the DoE has managed a continuous air monitoring station (CAMS) in the Shangshad Bhaban premises. The facility is capable of monitoring all criteria pollutants, except lead. Air pollution data on PM_{10}, $PM_{2.5}$, NO_2, NO_x, SO_x, CO, and O_3 levels were collected from CAMS. Threshold levels were obtained from the Bangladesh Government Air Quality Standard (2005) and the World Health Organization (WHO) Guidelines (2010). The Statistical Analysis Software (SAS) was used to determine significant levels of air pollution in Dhaka City. Air pollution data on factors such as PM_{10}, $PM_{2.5}$, NO_2, NO_x, SO_x, CO, and O_3 were assessed and the most significant

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ones identified in accordance to government and WHO guidelines. Brick kiln information in Dhaka was gathered from DoE's Ministry of Environment and Forest. This type of data was collected considering the number of clusterwise kilns, area, and position with time and risk. Operational cost and production-related data were obtained by direct field survey of brick kilns in areas surrounding Dhaka. The kilns were monitored for particulate matter (PM), sulfur dioxide (SO_2), oxides of nitrogen (NOx), carbon monoxide (CO), and carbon dioxide (CO_2). The emission factors for various pollutants were normalized to grams of pollutant/kilogram of the fired brick [13] [9]. The different types of brick kilns and the corresponding emissions were identified and compared with major air pollution gases such as SPM, CO_2, CO, and SO_2. These are based on Dhaka's air pollution condition [9] [13] [14] and on other brick kiln emission-related articles. To calculate the health effect from brick kilns, the survey looked into the level of emissions of air pollutants and the characteristics of the affected populations. The number of respondents in a hospital was selected using various criteria: volume of specific area, total population in the area, size, and quantity of hospitals and clinics. This survey involved patients who are in the respiratory medicine departments of hospitals and clinics. The survey questionnaires were pre-tested and conducted on randomly selected hospitals and populations. The cost of illness (COI) is composed of direct and indirect costs. The former refers to medical expenses incurred by the sick person; the latter pertains to the opportunity cost of filing to work or performing well in the job or any relevant duties. Hence, direct and indirect costs are computed as work loss days (WLD) and reduced activity days (RAD), respectively. For a given city, the quantitative assessment of the effect on health of outdoor air pollution is based on four components: i) pre- and post-air-pollution concentrations and exposure assessment; ii) size and composition of population groups exposed to current levels of air pollution; iii) background incidence of mortality and morbidity; and iv) concentration response (CR) coefficient functions. The CR coefficients indicate the expected change in the number of cases of health endpoint because of a marginal change in the ambient concentration of a particular air pollutant.

Below is a different health endpoint model [15]:

$$H_i = CR \text{ X } \sum_{J=1}^{j} (C_j \text{ x } Pop_j)$$

where;
Hi = the number of cases of heath endpoint i,
CRi = the CR coefficient for health endpoint i,
Cj = the estimated average annual concentration of PM_{10} from brick kilns for census unit j, and
Popj = the population in census unit j.

To estimate the monetary values of health damages avoided by reducing PM_{10} emissions from brick kilns, we used a combination of the following: (i) willingness to pay (WTP); (ii) figures from the economics literature, that is, "benefits transfer" approach; and (iii) estimates of health care costs based on the value of WLD. This step measures the effects on health in physical and monetary terms. Physical valuation translates the cases of mortality and morbidity into disability-adjusted life years (DALYs). For mortality, the number of DALYs depends on the age at the time of death [16]. This study used DALY values from [17] and [18]. With regard to the monetary value of the DALYs lost, the human capital approach is adopted, in which the value of one DALY lost is estimated as the gross domestic product per capita. The health impacts from pollution are valued on the basis of the DALY method. It provides a common measure of the disease burden for various illnesses and premature mortality [16].

Results

In Dhaka, PM was found to be the most harmful to public health and the environment as compared with other measured criteria pollutants. Among the groups of air pollutants, PM is thought to be the most important with respect to health effects and reduced urban visibility. The major sources of PM in Dhaka are diesel-powered vehicles, two-stroke engine gasoline vehicles, and brick kilns [19]. This study explored air pollution conditions in Dhaka, as well as the effects on human health of the surrounding brick kilns in the city. The yearly averages of PM_{10} and $PM_{2.5}$ were significantly high. The mean values were greater than the Bangladesh and WHO air quality standards. The pollution level of PM_{10} and $PM_{2.5}$ was highly significant, indicating high pollution in Dhaka. By contrast, analysis of other pollutants, such as SOx, NOx, SO_2, CO, and O_3, showed a low annual average, less than the quality standards of Bangladesh and WHO. The PM_{10} and $PM_{2.5}$ values were higher than the 24-h average Bangladesh national ambient air quality standard [12]. The pairwise comparison of the $PM_{2.5}$ means from 2002 to 2010 using the related case or sign-test can be used for testing. Of the 45 pairwise comparisons, only six were found to be significant. This implies that the mean $PM_{2.5}$ was increasing from 2007 to 2010. This pollution rate indicated other sources of pollution such as vehicles, industries, road dust, and others. The mean values from 2002 to 2005 increased and, in 2006, there was a little decrease. Then, from 2007 to 2010, the mean values increased again. Comparing the brick kilns' operating season (November to April) and non-operating season (May to October), 123 μ/m^3 was the $PM_{2.5}$ mean from the former; it was 35.4 μ/m^3 from the latter. It was proven that brick kiln emissions were higher during the operating season by 88 μ/m^3. Nevertheless, both seasons were significant and exceeded the threshold. Five months a year, the brick kilns are the city's main source of fine particulate pollution [16]. Similarly, the annual mean value of PM_{10} from November to April was 118 μ/m^3, higher than the non-operating season. Results show variations in mean values of $PM_{2.5}$ and PM_{10} mass concentrations in each season. The characteristic seasonal variation was observed for PM_{10} as well as for the fine particles, with elevated concentrations noted during the brick production period. Therefore, PM peak levels were very high during brick-making seasons. Both variables were observed to be much higher during the operating season than during the non-operating season, even considering brick production. Therefore, such pollutants are insignificant and have not exceeded the pollution level. Moreover, based on the air pollution level of Dhaka City, SO_2, NO_2, CO_2, and O_3 did not

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surpass standard values; only PM_{10} and $PM_{2.5}$ exceeded the standard, making the air polluted.

Brick Kiln Pollution Calculation in Dhaka City

The brick kilns made Dhaka one of the most polluted cities in Asia [16]. Brick kiln emissions were estimated over DMA—it ranged from 7 to 99 µg/m^3 (5th and 95th percentile concentration per model grid) at an average of 38 µg/m^3; as to spatial contributions from the surrounding clusters, 27% originated from Narayanganj (to the south with the highest kiln density), 30%from Gazipur (to the north with an equally large cluster spread along the river and canals), and 23% from Savar [20]. The existing FCK technology has a PM_{10} emission concentration of 32.2 µ/m^3. If all FCK were converted into zigzag kiln technology, PM_{10} emission would be 10.9 µ/m^3. Consequently, VSBK would be 4.6 µ/m^3 and HHK would be 11.9 µ/m^3. VSBK will have the lowest PM_{10} emission technology (Figure 1). In terms of $PM_{2.5}$ emission, VSBK also had the lowest emission while FCK had the highest.

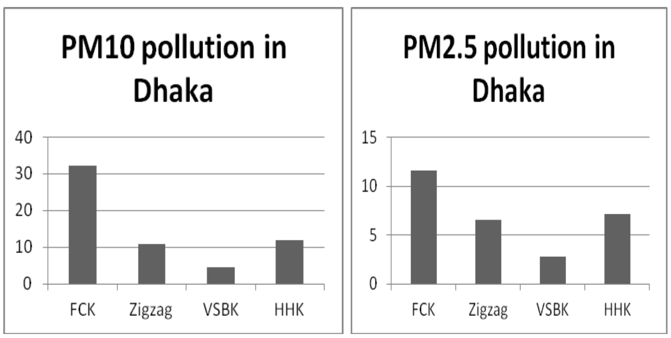

Figure 1. *PM_{10} and $PM_{2.5}$ pollution emanating from different brick kilns*

CO_2, CO, and SO_2 Emission Calculation from Different Brick Kilns

Carbon dioxide emissions are directly related to specific energy consumption (SEC) and carbon content of fuels being used in the kiln. Different kilns produce varying tons of CO_2 gases. From 1,136 FCKs, are produced 5.6 billion bricks. This type of kiln produces 2,719,992 tons of CO_2 gases. Other technologies such as zigzag, VSBK, and HHK produce 2,247,394; 1,685,545; and 1,123,697 tons of CO_2 gases, respectively. Comparing the four technologies, HHK had the lowest CO_2 emission. Based on baseline data, CO_2 emission of zigzag kilns will be reduced to 18%, VSBK to 39%, and HHK to 59%. HHK is the most efficient and best environment-friendly technology in terms of CO_2 emission. Figure 2 shows the CO_2 emission rate of the different types of kilns. Traditional polluting technologies are relatively profitable to entrepreneurs. However, when the costs of air pollution and CO2 emissions are factored in, they become undesirable. Cleaner technologies stand out as the most socially profitable [16].

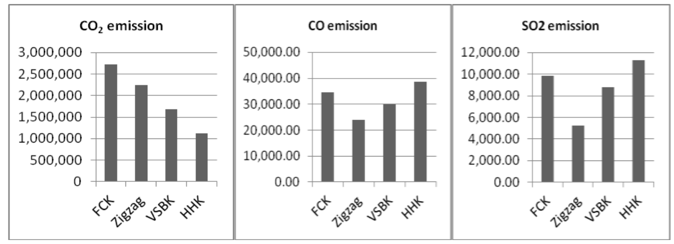

Figure 2. *CO_2, CO, and SO_2 emissions of different types of kilns*

Carbon monoxide emissions indicate incomplete fuel combustion. Figure 2 shows the different types of CO emitted by each type of kiln. FCK CO emission was 34,641 tons; that of Zigzag was 23,951 tons; VSBK, 29,980 tons; and HHK, 38,542 tons. This assessment proves that HHK gave the highest CO emission. FCK was second highest and zigzag kiln had the lowest CO emissions. Zigzag is thus the most preferable technology. With Zigzag technology, the monitored natural-draft Zigzag kiln has much lower CO emissions than the monitored forced-draft version. Good fuel-feeding and operating practices support this improvement. A comparison of CO emissions of the different types of brick kilns with that of existing brick kilns found that zigzag kilns reduced 31% of the emission and VSBK reduced 14%. But HHK produced 111% more pollution than the existing technology. Emission of SO_2 is one of the causes of concern over the environmental impact of using fuels as power sources. Figure 2 shows the different volumes of SO_2 gases produced by the different brick kilns. HHK had the highest SO_2 produced, followed by the existing FCK technology. The zigzag kiln produced the lowest SO_2. Compared with existing kilns, Zigzag reduced 48% of the SO_2 gas and VSBK reduced 11%. However, HHK increase emanating SO_2 emission by 14%.

PM_{10} and $PM_{2.5}$ Health Impact from Different Brick Kilns

Brick kilns have significant health impacts [15]. A high concentration of air pollutants such as suspended particulate matter (SPM) in Dhaka City has been reported. Brick kilns are one of the main contributors of air pollution emissions around the city [20]. Based on baseline data, air pollution in Dhaka is 25% PM_{10} concentration, which comes from brick kilns [14]. In Dhaka, Bangladesh, PM is the air pollutant most harmful to public health and the environment when compared with all other measured pollutants [19]. Considering Dhaka City's brick kiln emissions of PM_{10} and $PM_{2.5}$ concentration, the quantified health effects indicate varying risks posed by different technologies.

Morbidity Health Effect

The association between exposure to PM, especially fine PM_{10} or $PM_{2.5}$ (aerodynamic diameter less than 2.5 mm), and adverse health effects has been well established [21] [22]. The presence of fine particles in the air is linked to sickness and hospitalization as they cause a wide range of health effects, including respiratory symptoms (coughing, wheezing, reduced lung function), bronchitis, chronic obstructive pulmonary disease, lung cancer, heart attacks, arteriosclerosis, strokes, high blood pressure, and asthma [23]. PM_{10} and $PM_{2.5}$ are also linked to premature death

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from cardiovascular and respiratory diseases and lung cancer [24]. The fine particle levels (PM_{10}) are currently of most concern and cause the worst health problems. The relationship between levels of PM_{10} and excessive death rate has been confirmed [25]. This study focuses on air pollution-related health effects as described by the health effect model. The model calculated only PM_{10} and $PM_{2.5}$ because Dhaka City contains a significant level of only PM. With the model using PM pollution only, there were three types of value obtained: health effects, DALYs, and monetary values of the Dhaka PM_{10} and $PM_{2.5}$ pollution. Values tied to health effect can be divided into two, namely, morbidity and mortality. If we discuss PM_{10} and $PM_{2.5}$, individual morbidity can be gauged through respiratory hospital admissions (CRRHA), emergency room visits (CRERV), adult symptom days per year (CRARSD), adult restricted activity days per year (CRARAD), asthma attacks (CRAA), child chronic bronchitis (CRCCB), child chronic cough (CRCCC), and adult chronic cough (CRACB). Numerous studies have shown that high concentrations of PM may be linked to cardiovascular disease outcomes [26] [27] [28], respiratory disease outcomes [29] [30], and neurodegenerative disorders [31] [32]. The total morbidity health effect values were determined using the health effect model. The PM_{10} and $PM_{2.5}$ impacts of existing kilns (FCK) on total morbidity health effect were 29.66 health endpoints, while those of the other kilns Zigzag, VSVK, and HHK were 11.8, 5.0, and 13.0, respectively.. Similarly, Figure 3 shows the DALY and health effect monetary values.

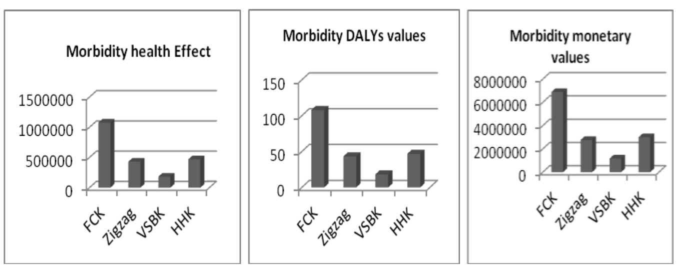

Figure 3. *Morbidity health effect, DALYs, and monetary values from different types of brick kilns*

Mortality Health Effect

The model found different types of health effects from gas emissions. For the existing (FCK) emission, the mortality health effect was 59,168 health endpoints. The other low-PM-emission technologies such as Zigzag, VSBK, and HHK had these respective health effect rates: 23,678; 10,014; and 25,759 health endpoints. Considering the effects of PM_{10} and $PM_{2.5}$ on brick kiln mortality, health effect mortality values were greater than morbidity values. In DALYs, it was discovered that values were much higher than other morbidity values. Similarly, the mortality health effect of monetary values was higher than all morbidity values. Long-term exposure to $PM_{2.5}$ increases the risk of non-accidental mortality by 6% per 10 $\mu g/m^3$ increase, independent of age, gender, and geographic region. Exposure to $PM_{2.5}$ was also associated with an increased risk of mortality from lung cancer (range: 15 to 21% per 10 $\mu g/m^3$ increase) and total cardiovascular mortality (range: 12 to 14% per 10 $\mu g/m^3$ increase) [33]. PM-related pollution was connected with each 10 $\mu g/m^3$ elevation in fine particulate air concentration and was associated with approximately 4%, 6%, and 8% increases in the risk of all causes of lung cancer and cardiopulmonary mortality [34]. If these health effects are compared against the other technologies, zigzag had almost three times lower values than the existing FCK technology; VSBK, almost six times; and HHK, is almost two times.

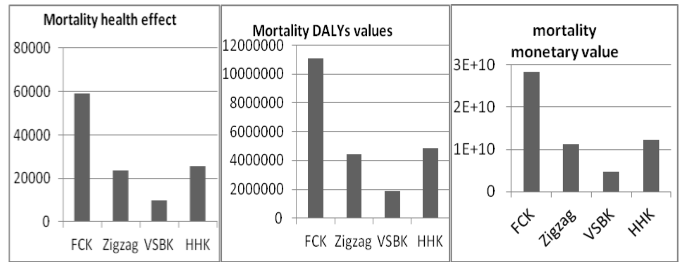

Figure 4. *Mortality health effect, DALYs, and monetary values from different types of brick kilns*

Figure 4 shows that the mortality DALYs values in other technologies (zigzag, VSBK, and HHK) were almost similar to or lower than those of FCK. PM_{10} and $PM_{2.5}$ emissions from brick production of the different kilns produced different quantities of emission and effects on health. Figure 33 shows that the existing type of kilns' (FCK) health impact, in monetary value, was 28.29 billion Taka per year per hospital or clinic, whereas the corresponding values for Zigzag, VSBK, and HHK using PM_{10} and PM2.5 emissions were 11.32, 4.788, and 12.32 billion Taka, respectively. Since there are 635 hospitals and clinics in Dhaka City, the health effect would be 635 times higher than those values. Considering the four technologies used in brick kiln production, VSBK technology gave the lowest health effect. If the baseline (existing brick kiln technology) of pollution created a 100% health effect level, the other technologies such as the zigzag kilns would be reduced by 60%, VSBK technology by 83%, and HHK technology by 57%. Replacing existing brick kiln technologies with cleaner ones (zigzag, VSBK, or HHK) would reduce the impact of brick pollution on premature mortality in Dhaka by 45-60% [16].

Conclusion

In this study, pollutants such as SO_2, NO_2, CO_2, and O_3 were found insignificant as they did not exceed the pollution level. Only PM_{10} and $PM_{2.5}$ exceeded the standard and made the air polluted. With PM_{10} and $PM_{2.5}$ emission as basis, VSBK was judged the best but Zigzag was regarded more environment-friendly. As to CO_2 emission, HHK was seen as a good technology, but VSBK was better. With CO and SO_2, was found zigzag the best, followed by VSBK. However, air pollution in Dhaka City, with PM_{10} and $PM_{2.5}$ emissions, was already at a significant level. Considering the four brick kiln technologies, VSBK had the least health effect considering PM_{10} and $PM_{2.5}$ emissions. If the baseline (the existing brick kiln technology) created a 100% health effect, the other technologies such as Zigzag kilns would reduce it by 60%; VSBK by 83%, and HHK by 57%.The different types of brick kilns have an effect on air pollution in Dhaka City and there is a consequent health impact. Researchers found that the existing technology has the most adverse health effects. VSBK was considered the most environment-friendly technology, followed by VSBK

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and, lastly, by zigzag. In terms of improving ambient air quality, Zigzag, HHK, and VSBK technologies were very effective.

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