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Spatiotemporal Variation of Brick Kilns and it's relation to Ground-level $PM_{2.5}$ through MODIS Image at Dhaka District, Bangladesh

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Abstract: The air quality of Dhaka has become severe due to numerous brick kilns, construction, demolition, biomass burning, heavy traffic, transboundary effect, etc. This study identified the relationship between the spatiotemporal variation of brick kilns with $PM_{2.5}$ concentrations in three sub-districts of Dhaka, namely- Dhamrai, Savar, and Keraniganj. Spatial data retrieved from Google Earth for assessing the temporal changes of brick kilns and Moderate Resolution Imaging Spectroradiometer (MODIS) data for $PM_{2.5}$ collected from NASA online database. Remote sensing technique and ArcGIS 10.2.1 tool used for analyzing the spatiotemporal variability of $PM_{2.5}$ concentrations. The results show that the number of brick kilns increased to 307, 497 and 551 in 2006, 2010 and 2018, respectively. Besides, the annual average of $PM_{2.5}$ concentrations in Dhamrai sub-district was 58.6, 58.9 and 64.8 μg/m^3, while 58.6, 58.2 and 64.5 μg/m^3 in Savar and 57.7, 56.7 and 63.1 μg/m^3 in Keraniganj in 2006, 2010 and 2016, respectively. The findings portray that $PM_{2.5}$ concentration was almost three to four times higher than the Bangladesh National Ambient Air Quality Standard (BNAAQS) and World Health Organization (WHO) standards. Besides, there is an increasing trend has been found between concentration and brick kilns. Hence, standardization of the kiln efficiency through improved combustion techniques along with the promotion of sand bricks could be an effective solution to reduce emission from brick kilns in Bangladesh.
Keywords: Spatiotemporal, Brick kilns, Remote sensing, Particulate matter

INTRODUCTION

Dhaka is the 2nd most unlivable city of the world and air pollution is regarded as one of the influencing factors [1]. Several sources are responsible for air pollution in which brick kilns playing an important role in deteriorating the air quality in urban areas of Bangladesh. The conventional design of kilns and low-quality fuels are working as main polluting factors from brick kilns to the surrounding environment [2,3]. Emission from brick kilns is one of the major concerns for environmental degradation and air pollution in South-East Asian countries. Bangladesh, India, and China are the main contributors to produce bricks, which is the main raw material for building construction. Topsoil from agricultural land has been used as the main raw material for making bricks, resulting in a reduction for crop production [4,5]. Dhaka is a fast-growing city, with rapid urbanization posing 1230 brick kilns which are greatly contributing to air pollution in Dhaka city [6]. There are 18-20 tons of coal are burned in Fixed Chimney Kilns (FCK) to produce 1, 00,000 bricks in Bangladesh which emits approximately 39.8 tons of CO_2 to the environment [7]. Besides, around 3.5 billion bricks production consumes approximately 0.85 million tons of coal per year which are causing an estimated 2200–4000 premature deaths and 0.2–0.5 million asthma attacks per year in only greater Dhaka region [3,8]. Brick kilns of surrounding Dhaka are clustered in which some are comparatively more responsible for total air pollution in Dhaka city due to wind direction [9]. During the winter season, brick kilns contribute to 30-40% of the total ambient $PM_{2.5}$ pollution in the greater Dhaka region [9] whereas they contribute to 38% of the total air pollution of Dhaka metropolitan area [10,11].

Almost 92% of the brick industry is Fixed Chimney Kilns (FCKs), which are significant sources of pollutants [7,12]. The pollutants from brick kilns are mainly fine particles of coal, dust, organic matter and a small number of gases such as SO_2, NOx, H_2S, CO from burning of wood, rice husk, coal, sawdust, etc. The incomplete combustion of coal produces a large amount of sulfur dioxide and black carbon [13] which has detrimental effects on both human health and climate change [14,15]. Coal-burning releases particulate matter (PM) and other toxic gases into the air and wind movement promote air pollution in Dhaka.

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Every year, different types of ambient hazardous and toxic elements from brick industries are mixing up with air and soil, which pollutes the air as well as leads to increasing soil toxicity [16,17]. Moreover, the massive environmental effect from brick manufacturing also includes loss of land, change of land cover pattern, and reduction of fertility and humus soil [18-21]. It has been estimated that every year 0.7-1% arable lands are diminishing due to the setup of brick kilns industry in Bangladesh [22-24]. Apart from, Agricultural soil may also become polluted by fly ash, heavy metals and non-ferrous metals emerging from the brick kiln emissions [25]. It severely affects the growth and yield of crops, decreases the carbon content and reduces the water storing capacity [4,26,27].

Hence, it is imperative to calculate the concentrations of PM and gaseous pollutants from each cluster around Dhaka district and find out their contribution to the degradation of the environment. This study aims to assess the temporal changes of brick kilns since 2006-2018 and find out the trend of $PM_{2.5}$ pollution from brick kilns. Besides, this study also provides an overview of $PM_{2.5}$ concentration between brick kilns and non-brick kilns occupied areas.

METHODOLOGY

Study Area

There are six sub-districts under Dhaka district, among which three contain numerous brick kilns, namely Dhamrai (between 23°49' and 24°03' north latitudes and in between 90°01' and 90°15' east longitudes.); Savar (between 23°44' and 24°02' north latitudes and in between 90°11' and 90°22' east longitudes); and Keraniganj (between 23°37' and 23°47' north latitudes and in between 90°13' and 90°29' longitudes) (Figure 1).

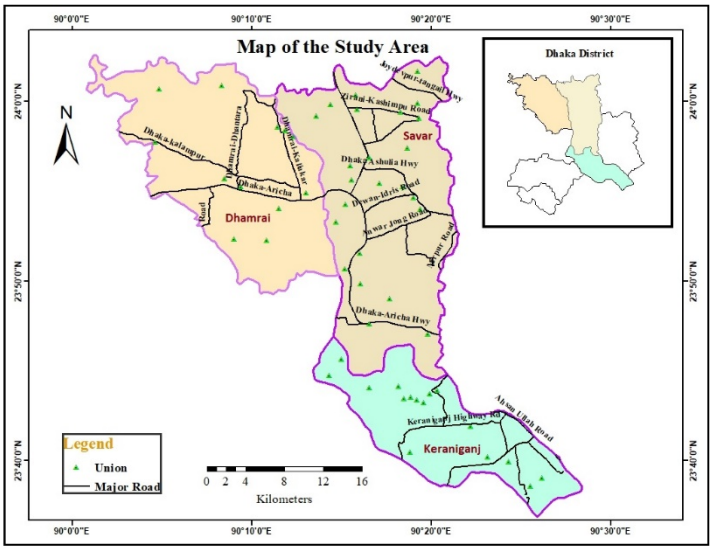


Figure 1. Map showing locations of the study sites

Data Collection and Analysis

The number of brick kilns has been extracted from Google earth imagery for 2010 and 2018 (Table 1) while data for 2006 has been collected from another study of Bangladesh University of Engineering and Technology (BUET) [28]. Besides, the ground-level $PM_{2.5}$ data has been retrieved from global annual $PM_{2.5}$ grids, which was produced from MODIS, Multiangle Imaging Spectroradiometer (MISR) and Sea-Viewing Wide Field-of-View Sensor (SeaWiFS), Aerosol Optical Depth (AOD) with Geographically Weighted Regression (GWR) [29]. The $PM_{2.5}$ values have been extracted from raster grid in tabulated form using zonal analysis techniques of ArcGIS 10.2.1.

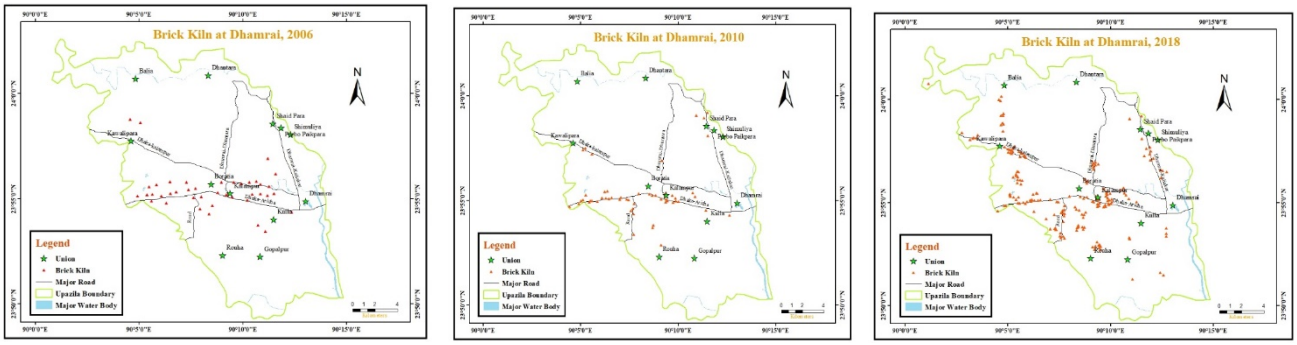
Table 1. Google Earth Data Sources and characteristics

Location Name	Year	Data Sources	Data output
Dhamrai, Savar, Keraniganj	2006	Hossain, (2007)	ArcMap 10.2.1
Dhamrai, Savar, Keraniganj	2010,2018	Google Earth	ArcMap 10.2.1

RESULTS AND DISCUSSION

Spatiotemporal Variation of Brick Kilns

Brick kilns in Dhamrai sub-district (Figure 2) have increased from 42 to 54 to 188 in the years of 2006, 2010 and 2018, respectively. In terms of brick kilns establishment, considerable change has been observed. In 2006, most of the brick kilns were found to be far from roads and water bodies, which afterward, came gradually closer to roads and river side. Besides, most of the kilns were found to be shifted to other places in 2010 and became distributive in 2018 compared to the aggregated condition in 2006 and 2010.



A B C

Figure 2. Spatiotemporal Change of Brick Kilns at Dhamrai sub-district in (A) 2006, (B) 2010, (C) 2018

In Savar sub-district, the number of brick kilns has increased rapidly from 2006 to 2010 but surprisingly decreased in 2018 (Figure 3). 140, 318 and 239 brick kilns were found in Savar in 2006, 2010 and 2018 respectively. In terms of brick kilns distribution, newer areas were found to be added in 2010 than 2006 and most of them were situated in the riverbank and near to the water bodies. In Keraniganj sub-district (Figure 4), no considerable temporal change is observed since the number of brick kilns was 125 in 2006 and 2010 which decreased to 124 in 2018 respectively. However, the kilns in 2006 were in grouped clusters while they found scattered in 2018 with moving towards the river bank.

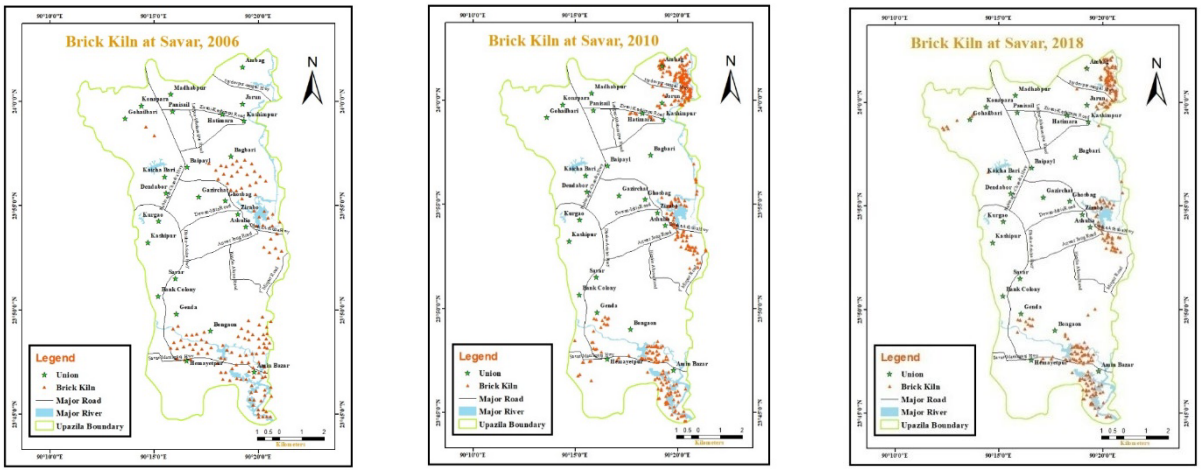


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Figure 3. Spatiotemporal Change of Brick Kilns at Savar sub-district in (A) 2006, (B) 2010, (C) 2018

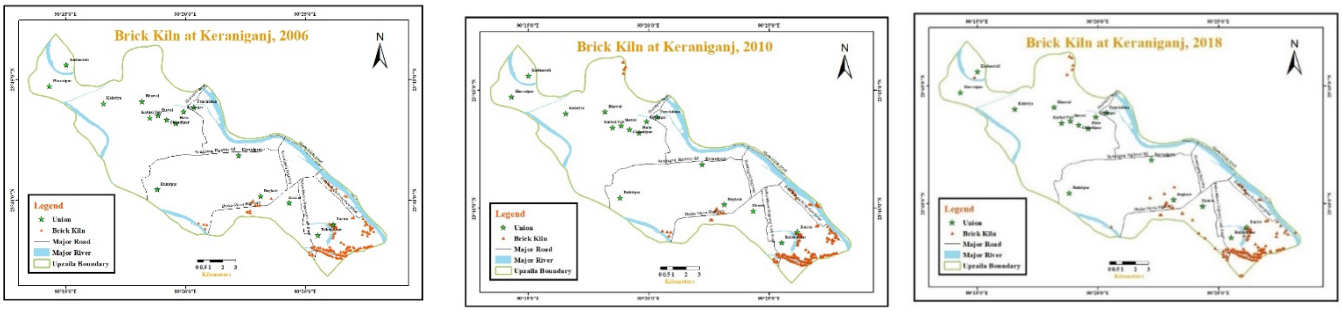

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Figure 4. Spatiotemporal Change of Brick Kilns at Keraniganj sub-district in (A) 2006, (B) 2010, (C) 2018

The maximum number of brick kilns is found in Savar from 2006 to 2018 whereas rapidly increasing in Dhamari while comparatively slow in Keraniganj that remained unchanged respectively (Table 2). Moreover, most of the kilns around Dhaka are observed to be aggregated over all the areas in 2006 which gradually became scattered later and moved towards the river bank for easy transportation. Consequently, the soil pH and the amount of organic carbon are supposed to be decreased rapidly which may cause to decrease the soil fertility and eventually loss of crop production [4]. The increasing trend of brick kilns in Dhamrai is attributed to the availability of open spaces near the river and road networks. The dotted lines show the increasing trend of brick kilns in the study areas (Figure 5).

Table 2. Number of Brick Kilns in different time frame

	2006		2010		2018	
Location/Year	No.	%	Number	%	Number	%
Dhamrai	42	14	54	11	188	34
Savar	140	45	318	64	239	43
Keraniganj	125	41	125	25	124	23
Total	307	100%	497	100%	551	100%

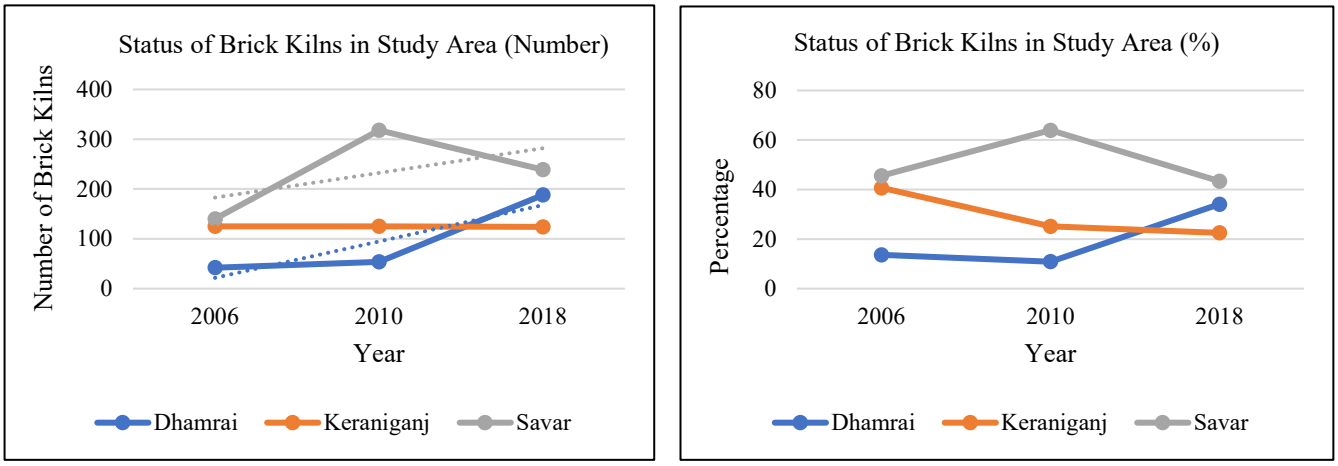

Figure 5. Status of Brick Kilns in Study Area

Concentrations of $PM_{2.5}$

The MODIS data for Dhamrai showed that, the annual $PM_{2.5}$ concentrations were 58.6±0.30 µg/m^3, 58.9±0.32µg/m^3, 64.8±0.35µg/m^3 whereas those for Savar were 58.6±0.28µg/m^3, 58.2±0.53µg/m^3 and 64.5±0.30µg/m^3 and for Keraniganj, those were found to be 57.7±0.35µg/m^3, 56.7±0.19µg/m^3, 63.1±0.13µg/m^3 in the years of 2006, 2010 and 2016 respectively (Table 3).

Table 3. Annual concentrations of $PM_{2.5}$ in different time frame

Category	Location /Year	2006 (µg/m³)	2010 (µg/m³)	2016 (µg/m³)	BNAAQ Standard (µg/m³)	WHO Standard (µg/m³)
Brick Kilns Occupied Areas	Dhamrai	58.6 ±0.30	58.9±0.32	64.8±0.35	15	10
	Savar	58.6±0.28	58.2±0.53	64.5±0.30		
	Keraniganj	57.7±0.35	56.7±0.19	63.1±0.13		
Without Brick Kilns Areas	Dhaka Metro	57.4±0.35	57.4±0.47	63.6±0.51		
	Dohar	57.2±0.41	56.5±0.42	61.8±0.50		
	Nawabganj	57.5±0.31	56.7±0.44	62.4±0.49		

In the year of 2006, the average concentrations of $PM_{2.5}$ were 58.6 µg/m³ at Dhamrai and Savar while that in Keraniganj had less concentration (Figure 6). But, overall Dhamrai had the maximum concentration of $PM_{2.5}$ across different years. Surprisingly, the brick kiln (Dhamrai, Savar, Keraniganj) areas contain an average higher concentration of annual $PM_{2.5}$ than other areas. During the dry season, the pollutants from the north cluster (Dhamrai and Savar) of brick kilns may contribute to the total air pollution in the southern part of Dhaka district due to wind direction [9].

There are many factors e.g. old and expired busses, three-wheeler vehicles, cars, trash burning, road dust, transboundary pollutants are affecting the variation of $PM_{2.5}$ concentration at different locations in Dhaka district in which brick kilns are one of them. Besides, most of the brick kilns burn the coal to produce the bricks. This coal playing a significant role in increasing pollution from brick kilns. Dhamrai and Savar are located in the northern part of Dhaka whereas Keraniganj, Dohar and Nawabganj are located in the southern part. Dhaka district is surrounded by Gazipur district in the north and Narayanganj district in the south. Gazipur (Gazipur Sadar and Kaliakair) and Narayanganj (Narayanganj sadar and Rupganj sub-district) contain a considerable number of brick kilns [28]. In the central part of Dhaka district, a critical situation is observed due to increasing rate of pollution from brick kilns besides other sources e.g. vehicular emission, construction work, burning of waste materials, etc. [30]. The brick kilns considerably contribute to the air pollution problems caused by $PM_{2.5}$ in Dhaka, especially during manufacturing season of bricks [31]. Figure 7 indicates that, Dhamrai and Savar have the maximum concentration of $PM_{2.5}$ while the minimum concentration was found in Dohar, Nawabganj, Keraniganj, and Dhaka municipal area.

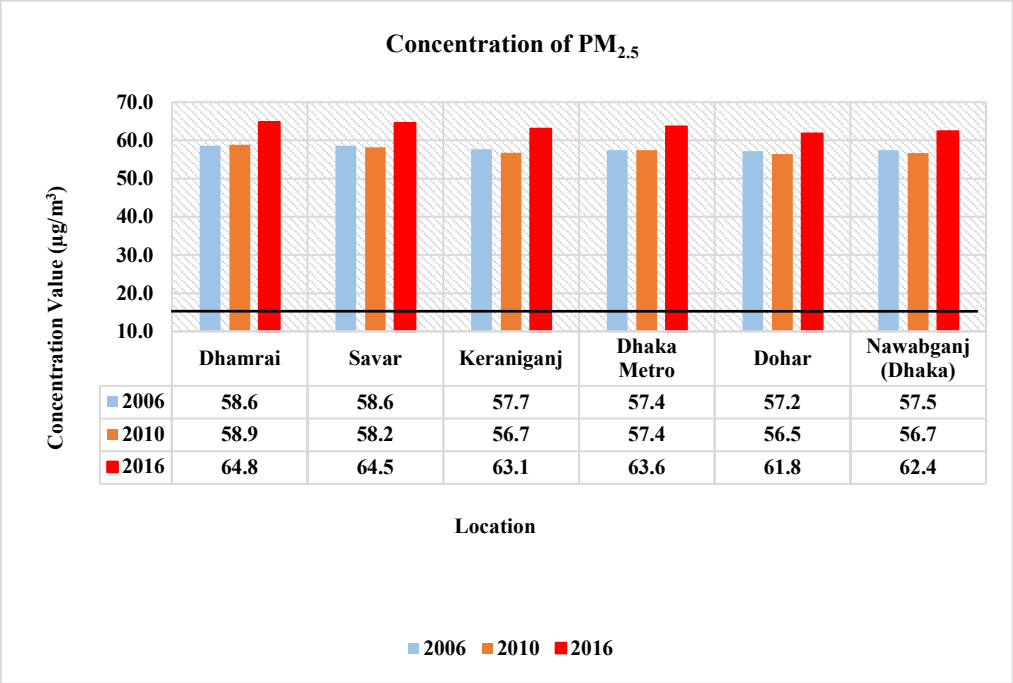

Figure 6. Concentrations of $PM_{2.5}$ at Different Locations in Dhaka District

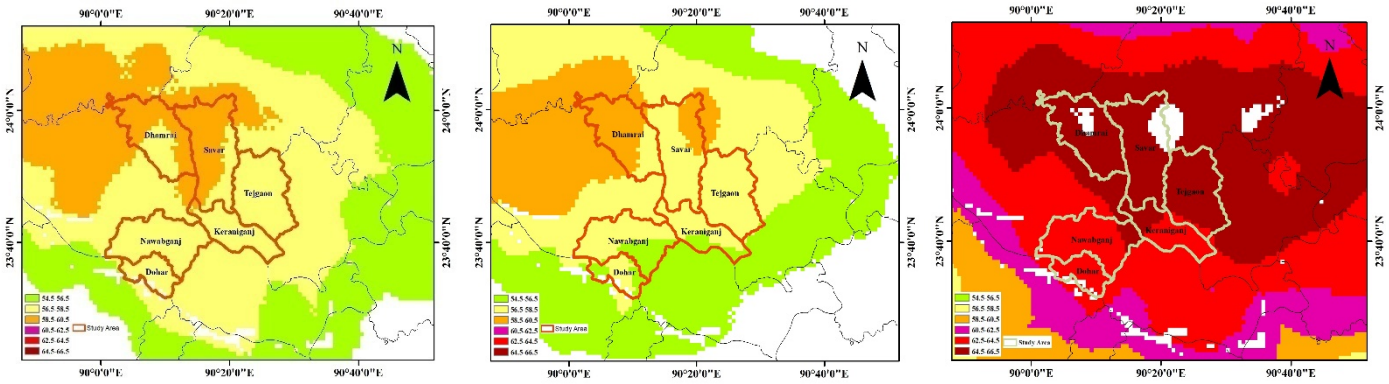

Figure 7. Concentration of $PM_{2.5}$ in Different Parts of Dhaka District for (A) 2006, (B) 2010, (C) 2016

In Dhamrai sub-district, the trend line of $PM_{2.5}$ is increasing (R^2=0.78) with the number of brick kilns. Savar is in the 2nd position in terms of the increasing trend (R^2= 0.69) while Keraniganj (R^2=0.62) is in the lowest position. So, the overall increasing trends of $PM_{2.5}$ are high considering the number of brick kilns in the study area (Figure 8).

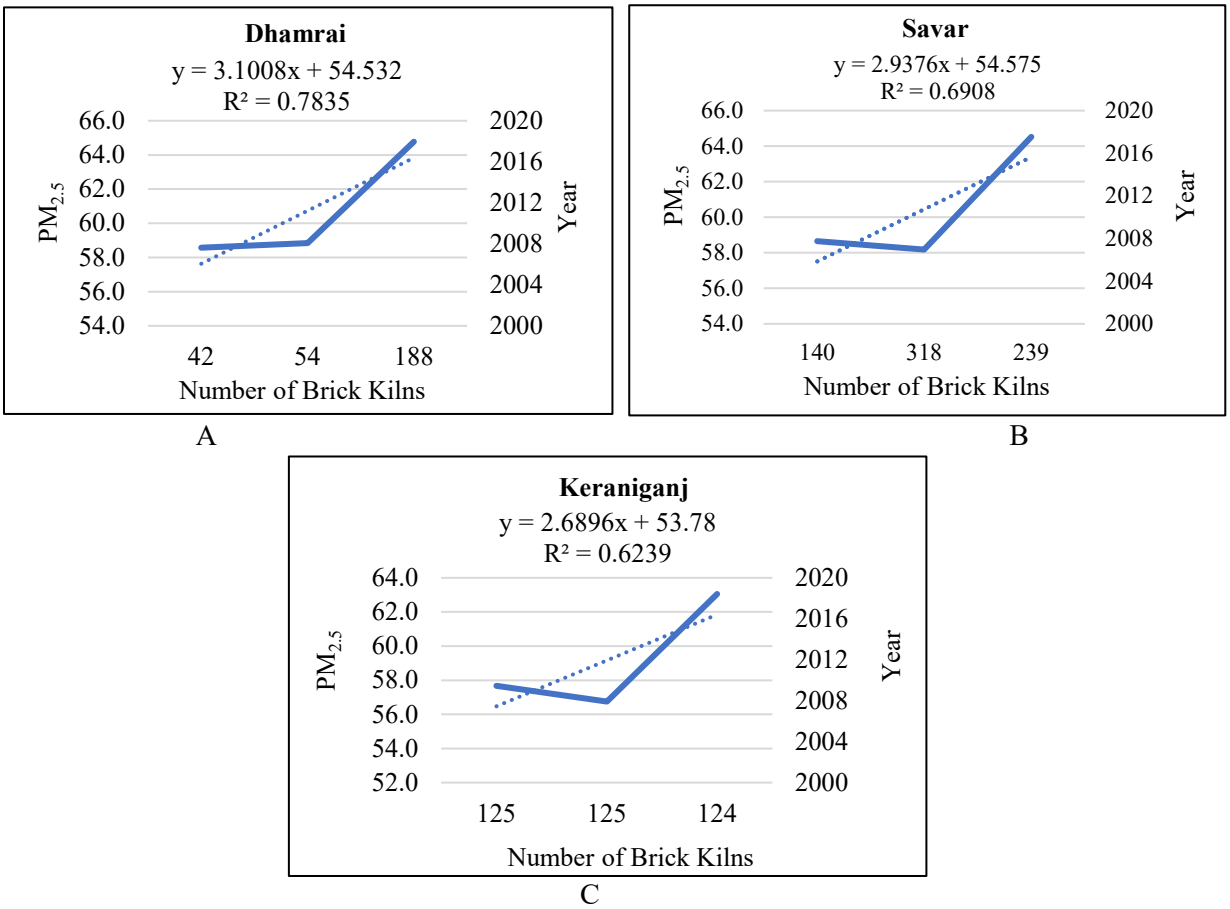

Figure 8. Trends of $PM_{2.5}$ Concentrations in (A) Dhamrai, (B) Savar, and (C) Keraniganj

CONCLUSION

Brick kilns contribute significantly to the deterioration of air quality in Dhaka city, especially during the heightened manufacturing season [10,11,32,33]. There are few studies have been conducted on brick kilns induced air pollution in Bangladesh. The present study shows that the overall number of brick kilns has been increased from 307 to 551 since 2006 to 2018 which also lead to increase in $PM_{2.5}$

concentrations from 58.07μg/m^3 to 64.13 μg/m^3 respectively. Moreover, $PM_{2.5}$ concentrations were also found to be increasing for both brick kilns occupied (58.07, 57.93 and 64.13 μg/m^3) and non-occupied areas (57.37, 56.87 and 62.60 μg/m^3) though the concentration is higher in occupied areas than the non-occupied areas for 2006, 2010 and 2016 respectively. Also, $PM_{2.5}$ concentration exceeded the BNAAQS value for every observation made in the study region, which should be addressed immediately. Continuous data monitoring facilities were not available to make the correlation between brick kilns and $PM_{2.5}$, which is the major limitation of this study. This study could be employed for other brick kiln locations and other pollutants besides $PM_{2.5}$ for better understanding of the pollution level. From the above data interpretations and discussions, it is obvious that more studies assessing more pollutants are needed to determine the effects of pollution caused by brick kilns in Bangladesh. It is very difficult to eliminate air pollution for a developing country like Bangladesh. But, we can adopt some mitigation steps to reduce the extent of pollution from brick kilns. The government can take initiatives to enforce the existing laws and regulations, such as the ban of traditional brick kilns, and carry out a study to promote improved Zigzag Kiln's design and reduce emission. The government can also implement continuous monitoring near the brick kilns for a better understanding of the relationship between stack emission and overall air pollution levels. By promoting environment-friendly sand bricks, it would be a great deal to reduce pollutions from brick kilns in Bangladesh.

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Conflict of Interest: The authors declare that they have no conflict of interest.
Consent: There were no human involving issues during this study.

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