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Geo-spatial assessment of temporal variation of greenhouse gases emission using GIS in Jahangirnagar University, Bangladesh

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Abstract

To assess the present scenario of GHGs (CO_2 and CH_4) emission and its distribution, day time emissions of CO_2 and CH_4 in August 2013 and 2014 in Jahanginagar University area were studied using statistical analysis and GIS interpretation. In 2013, maximum value of CO_2 was 500 ppm which was found in Bishmile bio gas plant, Prantic gate and Dairy gate characterized by solid waste dumping site and high way road areas. Similarly in 2014, maximum value of CO_2 was 600 ppm which was found around the high way road site area. In 2013 and 2014 maximum value of CH_4 was 3500 ppm and 4000ppm respectively which was found in Bishmile situated in the Northern site of study area. These sites are characterized by solid waste dumping site and biogas plant area. The results of the geospatial calculations show that in 2013, 43.355% of total area covers 357.143 to 385.714 ppm concentration of CO_2 while in 2014, 45.896% of the total area covers 385.714 to 428.571 ppm concentration of CO_2. Apart this in 2013, 38.604% of total area covers 621.418 to 1042.18ppm concentration of CH_4 while in 2014, 39.168 % of the total area covers 856.583 to 1434.818 ppm concentration of CH_4. From the spatial and temporal analysis it can be said that concentration of CO_2 and CH_4 in this area in a rising trend. This study would also implicitly provide a mechanism to monitor potential sources of CO_2 and CH_4 as well as their adverse contribution to enhance GHGs emissions.

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Introduction

Greenhouse gases (GHGs) have been recognized to be responsible for global warming and climate change (IPCC, 2007b). Emissions of GHGs such as carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) are ever increasing and other gases such as oxides of nitrogen (NO_x), carbon monoxide (CO), and sulphur dioxide (SO_2) often accompany the release of these GHGs (Sookun *et al.,* 2014). Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. Carbon dioxide (CO_2) emissions are produced in our daily lives through burning fossil fuels to meet essential needs such as electricity, heating, and transportation. As a major component of greenhouse gas emissions, increased CO_2 emissions due to anthropogenic activities have been suggested to contribute to global warming. Carbon dioxide (CO_2) has significantly increased over recent centuries with atmospheric concentrations rising by 31% since 1750, with fossil fuel burning accounting for approximately three quarters of the increased emissions (IPCC, 2001). Methane, a greenhouse gas, has 23 times the global warming potential of carbon dioxide over a 100-year time horizon (IPCC, 2001). Methane (CH_4) is a radiatively active trace gases whose abundance in the atmosphere has more than doubled during the past several hundred years and continues to rise (Cicerone and Oremland, 1988; Dlugokencky *et al.,* 1998; Shipham *et al.,* 1998). This increase is correlated with increasing human population (Rasmussen and Khalil, 1984). CH_4 contributes to global warming as a result of its ability to trap heat, 21 times more effectively than carbon dioxide over a 100-year period (IPCC, 2001). Also, the oxidizing capacity of the atmosphere is diminished by increasing CH_4 through reaction with hydroxyl radicals. The short lifetime of CH_4 in the atmosphere, about 9 years compared with 120 years for carbon dioxide, coupled with its potency makes it an ideal candidate for emissions reduction (WMO, 1998; IPCC, 2001).

Jahangirnagar University is the only residential university in Bangladesh close to the capital city Dhaka. So far, no efforts have been made to monitor ambient concentration of CO_2 and CH_4 in Jahangirnagar University and its surroundings. The present study focuses on direct measurements and to develop a general profile of temporal variations in the ambient concentration of CO_2 and CH_4 in this area.

Material and methods

2.1 Study area: Jahangirnagar University situated in Savar Upazila, 32 kilometers away from the capital city Dhaka (Fig. 1). Total area is 697.56 acres (2.8 km²) and about 17,000 people staying here. This area encompasses with approximately 25% seasonal and permanent water bodies and about 20% vegetation cover. In the Northern site of this university a landfill site and a biogas plant is situated.

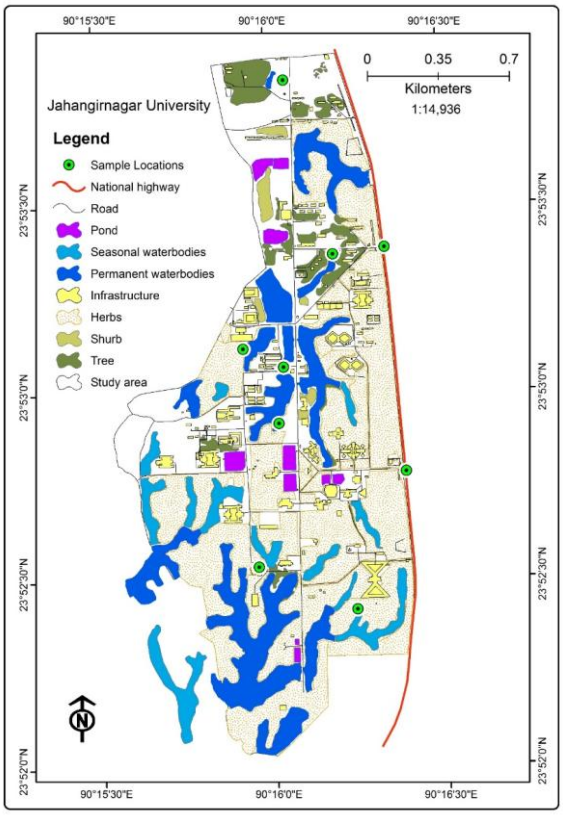

Fig. 1. Map of the Study Area.

Data collection

Concentration of CO_2 and CH_4 was measured by Landfill Gas analyzer LFG20 from Jahangirnagar University area in August of 2013 and 2014 consequently. Data were measured around 11.00 am

to 3.00 pm (GMT+6.00). Landfill Gas analyzer LFG20 was settled at 3.0 m height from ground level during operation (Sahay and Ghosh, 2013). Data was collected from 9 selective points (Table 1).

Table 1. Name of the sampling sites with GPS locations.

Site ID	Name of the site	Latitude	Longitude
S1	Bishmile bio gas plant	23.89722	90.2675
S2	Prantic gate	23.88972	90.27222
S3	Prantic mosque	23.88944	90.26972
S4	Al-Beruni hall	23.88528	90.26528
S5	Fazilatunnesa Hall	23.88444	90.26722
S6	New Register building	23.88194	90.26694
S7	Gymnesium	23.87556	90.26583
S8	Dairy gate	23.87972	90.27306
S9	MH Hall	23.87361	90.27056

Data preparation

GPS location of the monitoring sites was measured using Garmin GPS. Collected percentage data of CO_2 and CH_4, then converted them into ppm using the following equations.

X (ppm) = 10000 × X (%)

GIS based methods

ArcGIS-10.2 is used for the analysis of temporal variation of GHGs emission in the study area. Geo-databases were developed and Geo-referenced with GCS_WGS_1984. The features were projected using WGS_1984_UTM_Zone_45N (Universal Transverse Mercator).

Spatial Analysis

IDW (Inverse Distance Weighted) is an interpolation technique in which interpolated values are made based on measurement values at nearby locations weighted only by distance from the interpolation location. This technique does not assume any type of spatial relationship, except the basic assumption that nearby points ought to be more closely related to one another than more distant points (Davis, 1986; Maguire *et al.*, 1991). The only complication is the resulting contour is a function of sampling density. The data points define the interpolation, the resulting contours are fully representative of the data. This is not always true of kriging and other contour models (Gerlach *et al.*, 2001).

Spokas *et al.* (2003) stated the formula for IDW which used for spatial distribution of CO_2 and CH_4 calculation by the way

$$Z_{est}^{j} = \frac{\sum(\frac{z_i}{(h_{ij}+S)^2})}{\sum(\frac{1}{(h_{ij}+S)^2})}$$

Where, Z_{est}^{j} is estimated value for location j, z_i is measured sample value at point i, h_{ij} is distance between Z^j_{est} and z_j; and S is smoothing factor (0 was used).

Results and discussion

Results include the general findings of day time emissions of CO_2 and CH_4 in August 2013 and 2014 in Jahangirnagar University. Spatial analysis is carried out for the distribution which represent the temporal variation of the emissions of CO_2 and CH_4 in the study area.

Statistical Analysis

In 2013, maximum value of CO_2 was 500 ppm, which was found in several sites (values and site names are given in Table-1 and Table-2). These sites are characterized by solid waste dumping site and high way road sites. The minimum and average value of CO_2 in 2013 were 300 ppm and 388.889 ppm respectively (Table-2). In 2014, maximum value of CO_2 was 600 ppm which was found around the high way road site area. The minimum and average value of CO_2 in 2014 were 300 ppm and 422.222 ppm respectively (Table-2).

Comparing with the measured values of CO_2 in 2013 and 2014 shows that in some locations the concentration of CO_2 remains same and in a few locations CO_2 concentration increased (Fig. 2). Average concentration of CO_2 is increased in 2014 comparing with the concentration of 2013 (Fig. 3). In

2013, maximum value of CH_4 was 3500 ppm which was found in Bishmile, situated in the Northern site of study area. These sites are characterized by solid waste dumping site and biogas plant area. 2300 ppm and 1700 ppm concentration of CH_4 were found in some small scale waste dumping sites (Table 2). The minimum and average value of CH_4 in 2013 were 100 ppm and 1077.778 ppm respectively (Table 3). In 2014, maximum value of CH_4 was 4000 ppm which was found in the similar region. The minimum and average value of CH_4 in 2014 were 100 ppm and 1144.444 ppm respectively (Table 3).

Table 2. Daytime measured concentration of CO_2 and CH_4 in the study area (2013 and 2014).

Site ID	Name of the site	2013				2014				Source Characteristics
		CO_2 (%)	CH_4 (%)	CO_2 (ppm)	CH_4 (ppm)	CO_2 (%)	CH_4 (%)	CO_2 (ppm)	CH_4 (ppm)	
S1	Bishmile bio gas plant	0.05	0.35	500	3500	0.05	0.4	500	4000	Solid Waste Dumping site
S2	Prantic gate	0.05	0.01	500	100	0.06	0.01	600	100	Bus Stand
S3	Prantic mosque	0.03	0.02	300	200	0.03	0.02	300	200	Lake
S4	Al-Beruni hall	0.04	0.23	400	2300	0.04	0.2	400	2000	Lake and small waste dumping site
S5	Fazilatunnesa Hall	0.03	0.08	300	800	0.04	0.09	400	900	Lake
S6	New Register building	0.03	0.07	300	700	0.03	0.08	300	800	Lake
S7	Gymnesium	0.04	0.02	400	200	0.04	0.01	400	100	Irrigated Land
S8	Dairy gate	0.05	0.02	500	200	0.06	0.02	600	200	Bus Stand
S9	MH Hall	0.03	0.17	300	1700	0.03	0.2	300	2000	Irrigated Land and small waste dumping site

Table 3. Descriptive statistics of GHGs (CO_2 and CH_4) emission in the study area.

GHGs	2013					2014				
	Min	Max	Range	Mean	Std. Deviation	Min	Max	Range	Mean	Std. Deviation
CO_2 (ppm)	300	500	300-500	388.889	92.796	300	600	300-600	422.222	120.185
CH_4 (ppm)	100	3500	100-3500	1077.778	1185.093	100	4000	100-4000	1144.444	1311.593

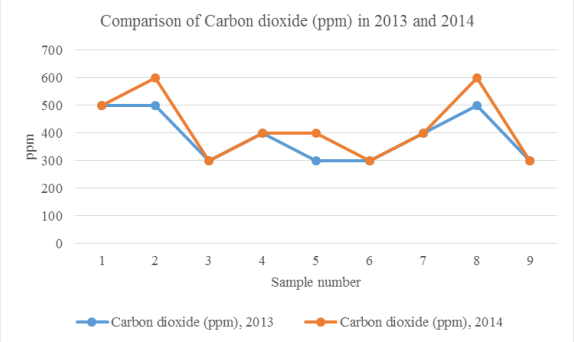

Fig. 2. Comparison of Carbon dioxide (ppm) in 2013 and 2014 with respective to their sampling number.

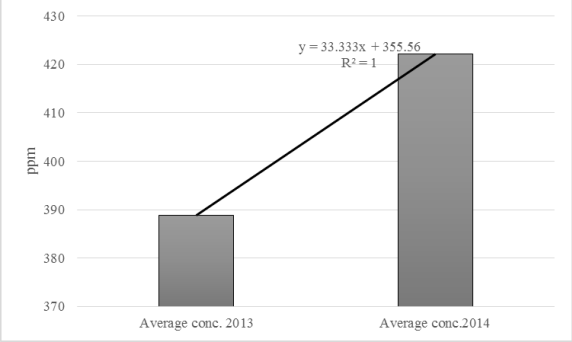

Fig. 3. Rising trend of Average Carbon dioxide concentration comparison with year (2013 and 2014).

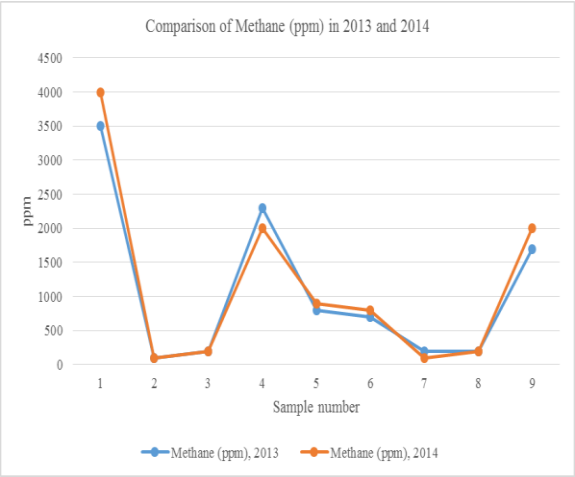

Fig.4. Comparison of Methane (ppm) in 2013 and 2014 with respective to their sampling number.

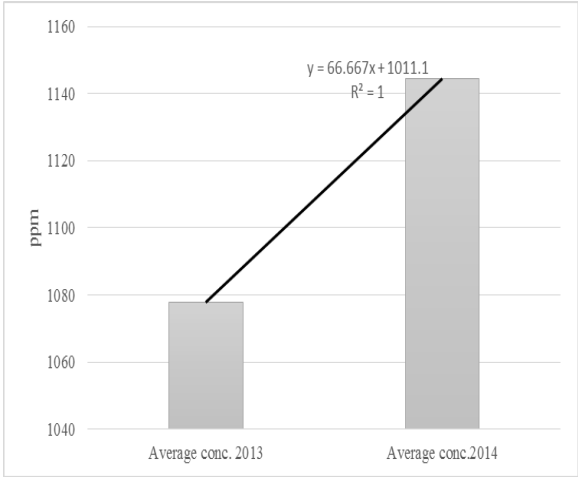

Fig. 5. Rising trend of Average Methane concentration comparison with year (2013 and 2014).

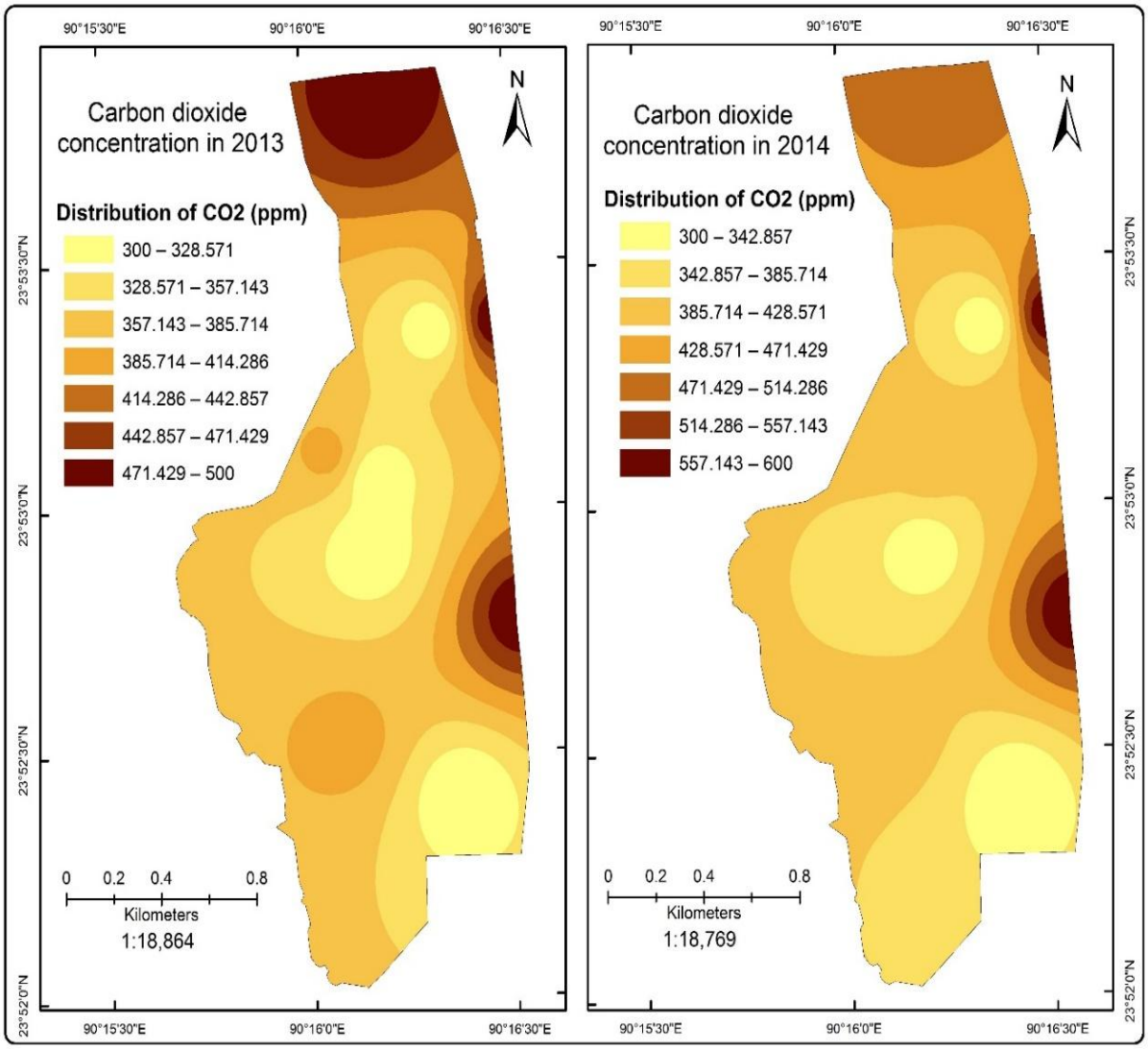

Fig. 6. Spatial distribution of Carbon dioxide concentration in 2013 and 2014.

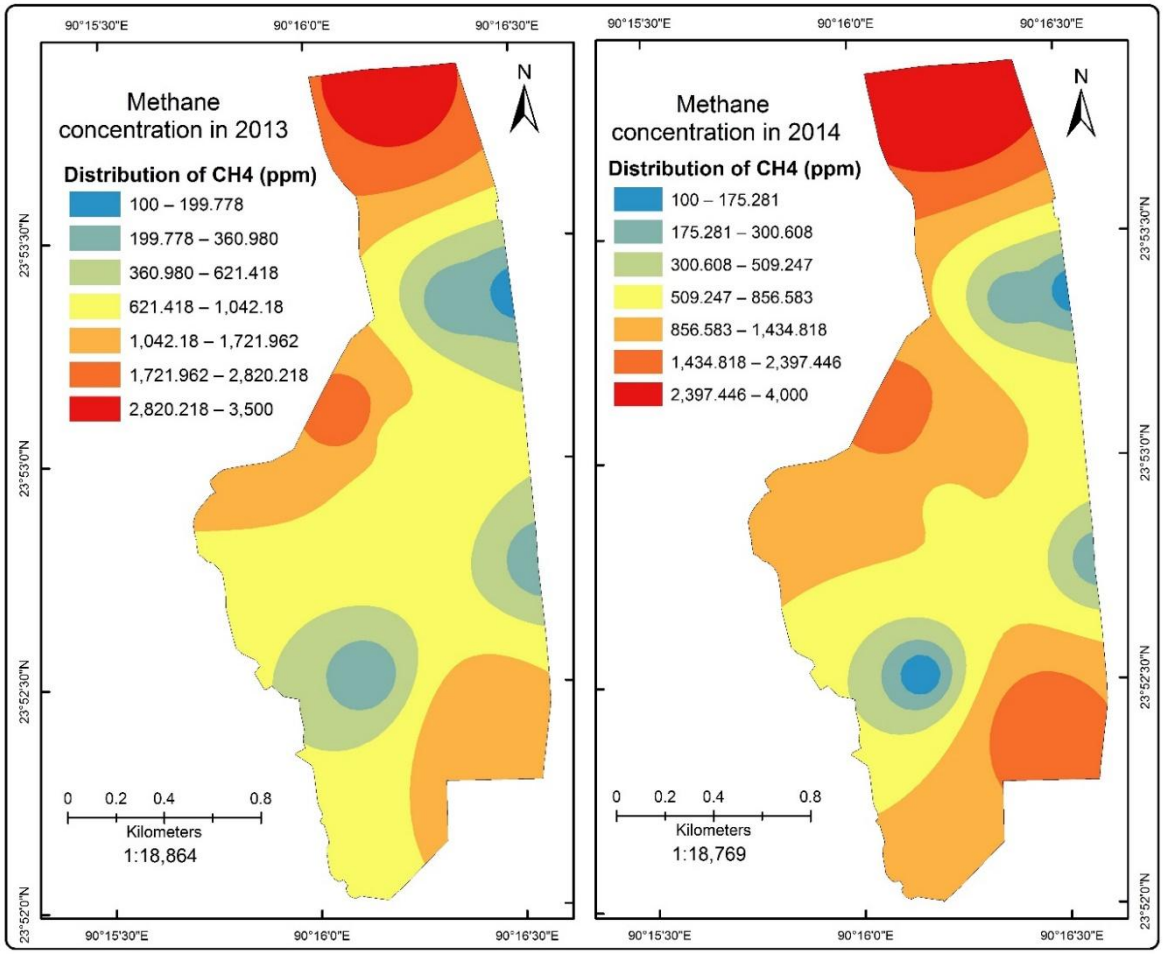

Fig. 7. Spatial distribution of Methane concentration in 2013 and 2014.

Comparing with the measured values of CH_4 in 2013 and 2014 shows that in few locations the concentration of CH_4 remains same and in some locations CH_4 concentration increased (Fig. 4). The average concentration of CH_4 is increased in 2014 compared with the concentration of 2013. Fig. 5 represents the rising trend of CH_4 with respect to the time in the study area.

Geo-spatial Analysis

Spatial Analysis is the process of examining the locations, attributes, and relationships of features in spatial data through overlay and other analytical techniques in order to address a question or gain useful knowledge (Wade and Sommer, 2006). Spatial analysis of the CO_2 emission in the study area provides an interpretation of the distribution of CO_2. From the observation of CO_2 distribution in the Bishmile landfill site area and surroundings of Dhaka-Aricha highway areas are under risk for high CO_2 emission. From the temporal analysis it is found that the concentration of CO_2 in this area in a rising trend (Fig. 2).

The results of the geospatial calculations show that in 2013, 43.355% of total area covers 357.143 to 385.714 ppm concentration of CO_2 while 385.714 to 500 ppm concentration of CO_2 covering 33.825% of the total area. In 2014, 45.896% of the total area covers 385.714 to 428.571 ppm concentration of CO_2 while 28.075% of the total area covering 428.571 to 600 ppm concentration of CO_2 (Table-4). This confirms the qualitative use as reported by Borjesson *et al.,* (2000).

Gratani and Varone (2005) reported near-surface CO_2 concentration measured at different sites in Rome from 1995 to 2004 with intervals. The concentrations

varied from 414 to 505 ppm at city center and showed strong correlation with the traffic density. The problem of contribution from vehicular exhaust affecting the measurements was reduced in our study as the monitoring sites were selected away from such streets. Javoy (2003), near surface CO_2 concentration measured in Paris, France reached as high as 950 ppm as monitoring was done close to streets with heavy traffic loads, while outside the city, it averaged 415 ppm. Though Jahangirnagar University is a residential area, but the CO_2 emission value is close to the urban area with high traffic density similar value of Rome and Paris city. About 9000 vehicles are passing everyday along with Dhaka Aricha highway. High traffic density is the main offender for the elevated CO_2 emission.

Table 4. Results of IDW analysis of CO_2.

Classes	CO_2 concentration (ppm) in 2013			CO_2 concentration (ppm) in 2014		
	Min Value	Max Value	Area Percentage	Min Value	Max Value	Area Percentage
1	300	328.571	6.605	300	342.857	5.537
2	328.571	357.143	16.215	342.857	385.714	20.492
3	357.143	385.714	43.355	385.714	428.571	45.896
4	385.714	414.286	12.767	428.571	471.429	16.582
5	414.286	442.857	10.531	471.429	514.286	8.212
6	442.857	471.429	5.934	514.286	557.143	1.847
7	471.429	500	4.593	557.143	600	1.434

Table 5. Results of IDW analysis of CH_4.

Classes	CH_4 concentration (ppm) in 2013			CH_4 concentration (ppm) in 2014		
	Min Value	Max Value	Area Percentage	Min Value	Max Value	Area Percentage
1	100	199.778	0.714	100	175.281	0.875
2	199.778	360.98	4.797	175.281	300.608	3.336
3	360.98	621.418	10.009	300.608	509.247	6.244
4	621.418	1042.18	38.604	509.247	856.583	25.602
5	1042.18	1721.962	32.272	856.583	1434.818	39.168
6	1721.962	2820.218	10.436	1434.818	2397.446	17.476
7	2820.218	3500	3.168	2397.446	4000	7.299

The results of the geospatial calculations show that in 2013, 38.604% of total area covers 621.418 to 1042.18ppm concentration of CH_4 while 1042.18 to 3500 ppm concentration of CH_4 covering 45.876% of the total area. In 2014, 39.168 % of the total area covers 856.583 to 1434.818 ppm concentration of CH4 while 24.775 % of the total area covering 1434.818 to 4000 ppm concentration of CH_4 (Table-4).

Padhy and Varshney (2000) measured the ambient methane levels at different sites in the urban area of Delhi from November 1994 to June 1995 at an interval of 15 days. The CH_4 concentration varied between 173 and 949.2 ppm with an average of 412.1 ppm. Major sources were poorly managed solid waste dumps, and choking sewers. Nguyen *et al.* (2010) analyzed the long-term patterns of urban CH_4 concentration in Seol, Korea. Measurements were taken at an urban site, 3.8 m above ground level and 1 m from the busy road for 11-year period. The average CH_4 concentration measured during the study period was 224 ppm.The implementation of a nationwide air quality control policy was responsible for low values, where as in several other studies, high levels of methane in the urban environment, ranging from 200ppm (Altshuller 1968), 200ppm (Graedel *et al.,* 1986), and 330 ppm (Rowland *et al.,* 1990) have been reported. As mentioned earlier Jahanginagar University is a residential area but the CH_4 concentration are higher than the reported average

value. Scattered solid waste dumping site around the university area and biogas plant adjacent of University emit higher emission CH_4.These reasons are similar with Padhy and Varshney (2000) work.

Conclusion

In 2013 and 2014 average value of CO_2 were 388.889 and 422.222 respectively and average value of CH_4 in 2013 and 2014 were 1077.778 ppm 1144.444 ppm respectively. Geospatial analysis is showed to measure area 2013, 38.604% of total area covers 621.418 to 1042.18ppm concentration of CH_4 while 1042.18 to 3500 ppm concentration of CH_4 covering 45.876% of the total area. In 2014, 39.168 % of the total area covers 856.583 to 1434.818 ppm concentration of CH4 while 24.775 % of the total area covering 1434.818 to 4000 ppm concentration of CH_4. Spatial assessment is showed that high way road along the University area are main offender for higher CO_2 emission. The present study shows the impact of anthropogenic activities on the ambient concentration of GHGs emission of Jahangirnagar University being close the capital city of Bangladesh. This study is expected to have significant implications in rapidly urbanizing cities in delivering baseline information about GHGs emission.

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