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TREND ANALYSIS OF GREENHOUSE GASES (CO_2, CH_4, N_2O) EMISSION FROM FOSSIL FUEL COMBUSTION IN BANGLADESH

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Abstract

This study was carried out to elicit the energy consumption status and emission trends of greenhouse gases (GHGs) including CO_2, CH_4 and N_2O from different fossil fuels (natural gas, crude oil, refined oil, furnace oil) combustion in Bangladesh from the year 2003 to 2015. IPCC modified guideline known as ALGAS was used for estimation of CO_2 emission and IPCC general method was used to calculate CO_2, CH_4 and N_2O emission from fossil fuels combustion in Bangladesh. It was revealed that emission of CO_2, CH_4 and N_2O showed a significant increasing trend from natural gas and refined oil. However, GHGs emission from crude oil fluctuated and did not show any regular trend. In the study, the highest GHGs emission was found from natural gas and lowest from furnace oil. Moreover, emission of GHGs from fossil fuels combustion showed the sequence of $CO_2 > CH_4 > N_2O$, whereas the footprint sequence of fossil fuel combustion showed the sequence of natural gas > refine oil > crude oil > furnace oil. The CO_2 emission from natural gas ranged from 10000 Gg to 500000 Gg. The CO_2 emission from natural gas showed increasing trends and was increased by 3 times during the 12 years of observations. However, CO_2 emission from crude oil ranged from 13. 71 Gg to 24. 50 Gg for the study period from 2003 to 2015. The average CO_2 emission from crude oil for the period of 2003 to 2009 was 12.2 Gg, and for the year of 2010 to 2015 it was 18.25 Gg. This finding indicates that increment of CO_2 emission during the year 2010 to 2015 may be due to enhanced consumption of crude oil by the recent establishment of quick rental power plants to meet enhanced nationwide power demand. Moreover, CH_4 emission from natural gas was doubled by the 12 years of observation with an enhanced consumption of natural gas from the base year 2003 to 2015.

Keywords: GHGs, CO_2, CH_4, N_2O, Natural gas, Crude oil, Furnace oil

Introduction

Emission of greenhouse gases (GHGs); carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are responsible for changes to global climate (IPCC, 2007). Infrared radiation is trapped by the GHGs, together with other atmospheric particles leads to global warming

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(Schneider, 1989). Burning of fossil fuels such as coal, natural gas, oil as well as solid waste, trees, wood and wood products burning lead-carbon dioxide (CO_2) and other gases enter into the atmosphere (Latake *et al*., 2015). For a long time, western countries have been facing problem with carbon dioxide (CO_2) emission from fossil fuel combustion. At present, GHGs emission has become a major cause of environmental degradation in developing countries as well. Therefore, due to rapid urbanization and industrialization, the world is experiencing dramatic levels of increases in air pollution (Liu and Diamond, 2005).

According to Kabir and Halim (2011), the net increase of atmospheric CO_2 is 10.65 billion tons per year. It is estimated that Bangladesh is responsible for the emission of about one-tenth of the world's CO_2. Methane (CH_4) is another GHGs, which raises the temperature even more than that of CO_2. Two-thirds of current emissions of methane is generally the by-product of human activities including the production of fuel oil and natural gas, deforestation, decomposition of garbage and sewage, raising farm animals and paddy production (Renato *et al*., 2005). The main sources of fossil fuel-related methane emissions are the release of natural gas from coal mining and leakage of gas during processing and distribution (Kabir and Halim, 2011). However, fossil fuel processing and intensive livestock farming are the primary cause of the increased CH_4 emission in the atmosphere (IPCC, 2007b).

Nitrous oxide (N_2O), influence greatly to global warming and ozone layer depletion. Although the atmospheric N_2O budget remains poorly understood, nitrification and denitrification in agricultural soil have been believed to be a crucial source of annual global N_2O emission (Mosier and Delgado, 1998). Fossil fuel burning has been predicted as one of the largest uncertainties in projections of GHGs concentrations in the atmosphere. While there has been a great deal of emphasis on carbon cycle since the natural sources and sinks of carbon, the fossil fuel component of the carbon budget remains uncertain, particularly at increasingly smaller spatial and temporal scales (Wofisy and Harris, 2007).

About 60% of the emitted CO_2 emit from natural gas combustion, while combustion of liquid fuels contributes 32% of the total CO_2 emission. However, due to energy production and development activities, Bangladesh emits huge amount of CO_2 every year especially from fossil fuels, gas fuels, liquid and solid fuels consumption (Amin *et al.*, 2012). Energy demands of Bangladesh are met by natural gas (56%), traditional biomass and waste (24%), oil (16%), coal (3%), and hydropower and solar (1% combined) (GRICCE, 2015). Moreover, in Bangladesh, the demand for electricity is expanding by an estimated 500MW per year due to population growth, industrialization, and use of modern household appliances. Considering the impacts of fossil fuel consumption in global warming as well as climate change and to create a national inventory, the present study analyzed 12 years trends of greenhouse gas emission from fossil fuel consumption in Bangladesh.

Materials and Methods

Study Area

Bangladesh is a South Asian country located between 20.34^0 N to 26.38^0 N and 88.01^0E to 92.12^0E with an area of 147,570 km^2 having a population of 161. 2 million (BBS, 2015). It has a humid, warm tropical climate that is fairly uniform throughout the country. Maximum temperatures range between 20^0 to 40^0C and minimum average just above 10^0C. Humidity ranges 63% to 90%, and precipitation range is 1100 to 5690 mm/year. Forest area covering the country is about 9%. The topographical height is only a few meters above mean sea level. The country has to experience natural hazards like devastating cyclones, water surges, and floods frequently. Here, consumption of fossil fuels for energy production, which is a crucial input for economic development and for improving the quality of life. Energy resources of Bangladesh comprise of commercial resources and biomass resources. The natural gas, coal, hydro-electricity, and petroleum products are the primary commercial energy sources. Bangladesh is also recognized for biomass fuel such as woods, agricultural residue, and animal dung (Azad *et al*., 2006; Bala, 1998).

Data source and analysis

Fossil fuels consumption data for the specific year (2003-2015) was collected from the different secondary sources such as BBS (Bureau of Statistics), Petro-Bangla website (www.petrobangla.org.bd.) and IPCC guideline for the conversion of greenhouse GHGs. MS Excel 2010 software was used for analyzing emission trend and preparing graphs, pie-charts, etc.

Estimation of CO_2 emission from fossil fuels combustion

National GHGs inventories for Bangladesh prepared by BCAS (Bangladesh Center For Advance Studies), which is used IPCC modified guideline for measuring CO_2 emission. This guideline also refers to ALGAS (Asia Least-cost Greenhouse Gas Abatement Strategy). Annual fuel consumption was calculated as follows:

Total supply = production + Import-export – stock change

Apparent consumption (Tj) is calculated by multiplying the total supply by conversion factor (Tj/kt). Again, multiplying the apparent consumption by carbon emission factor, carbon content (tC) is measured. The carbon content was converted as follows:

$$\text{Carbon Content (GgC)} = \frac{\text{Carbon Content (tC)}}{1000}$$

Estimation of CH_4 and N_2O *emission from fossil fuels combustion*

Emission of CH_4 and N_2O from fossil fuels combustion have been estimated by multiplying the mass of fuel consumed with an emission factor. According to IPCC (1996) the general method for estimation of CH_4, and N_2O is as follows:

Emissions = $\sum(EF_{ab} \times Activity_{ab})$

Where, EF = Emission Factor (Kg/Tj); Activity = Energy input (TJ); a = Fuel type; b = Sector activity.

Results and Discussion

Fossil fuel combustion status of Bangladesh

Fossil fuel combustion pattern for Bangladesh from the year 2003-2015 was shown in Fig. 1. During the study period (2003-2015) among others combustion of natural gas was highest (57%), followed by lube base oil (24%), refine oil (13%), crude oil (5%) and furnace oil (1%), respectively. Fig. 2 shows yearly consumption of natural gas, crude oil, refined oil, lube base oil and furnace oil for the year 2003 to 2015. From the Fig. 2, it is clear that the yearly consumption of natural gas and refined oil has been showing increasing trends during the study period. However, growing trends were absent in case of crude oil, furnace oil and lube base oil.

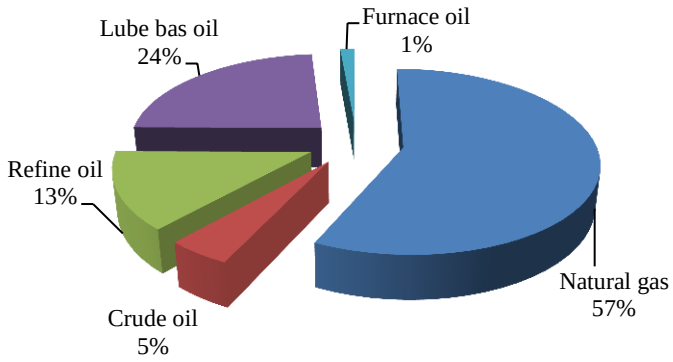

Fig. 1. Fossil fuel consumption pattern 2003-2015

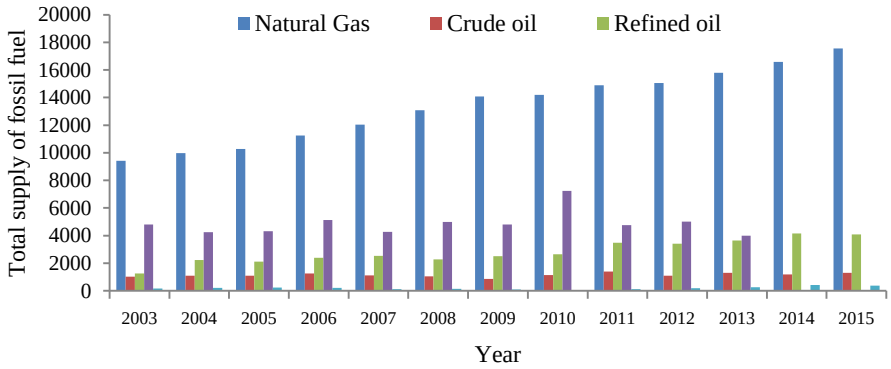

Fig. 2. Fossil fuel consumption of Bangladesh from the year 2013 to 2015

CO_2 emission trends from fossil fuels

The CO_2 emission from natural gas ranged from 25640.71 Gg to 48738.45 Gg (Table 1). These values were several times lower than that of India 230000 Gg (Sharma, 2007). The CO_2 emission from natural gas showed increasing trends from the year 2003 to 2015, which was increased by 3 times during the 12 years of observations (Fig. 3a). In comparison with others, natural gas was the highest emitters of CO_2, since natural gas is largely used for fertilizer production, power generation, vehicles, household cooking and industrial activity due to its availability and low cost in Bangladesh. Moreover, Azad *et al.* (2006) found the contribution of natural gas for CO_2 emission from 1977 to 1995 was 44% compared with other fossil fuels.

Table 1. Carbon dioxide emission from natural gas (Gg) during the study

Year	Natural gas (Gg)	Crude oil (Gg)	Refined oil (Gg)	Lube base Oil (Gg)	Furnace oil (Gg)
2003	25640.71	13.71	20.37	128.96	4.11
2004	27212.91	16.80	55.03	110.65	6.16
2005	28071.09	28.20	50.61	113.42	6.93
2006	30854.52	22.55	60.47	138.56	6.00
2007	33048.22	17.24	65.91	111.86	2.53
2008	36050.16	14.60	56.55	134.72	3.47
2009	38879.56	7.93	64.86	128.55	1.73
2010	39180.37	18.16	69.49	206.37	1.27
2011	41144.18	28.30	99.70	126.77	2.79
2012	41609.62	16.29	96.83	134.88	5.16
2013	43738.05	24.08	104.85	103.09	8.28
2014	45945.95	19.80	123.29	0.00	14.19
2015	48738.45	24.50	121.16	0.00	12.45

The CO_2 emission from refined oil was ranged from 20.40 Gg to 123.30 Gg during the study period (Table 1) having an increment in emission 7.32 Gg/year, which is several times lower than that of India 248025.14 Gg (Sharma *et al*., 2011). The CO_2 emission in 2015 from refined oil was increased by 6 times than that of the base year 2003 (Fig. 3c). However, CO_2 emission from crude oil ranged from 13.71 Gg to 28. 30 Gg for the study period 2003 to 2015 (Table 1). The lowest (6 Gg) and highest (25 Gg) CO_2 emitted from crude oil were measured by the year 2009 and 2011, respectively (Fig. 3b). Therefore, average CO_2 emission from crude oil for the period of 2003-2009 was 12.2 Gg and for the year of 2010 to 2015 it was 18.25 Gg. The increment of CO_2 emission during the year 2010-2015 may be due to enhanced consumption of crude oil by the quick rental power plants, which was introduced by the recent years. The CO_2 emission from furnace oil ranged from 4.10 Gg to 14.2 Gg (Table 1). During the observation, the highest and lowest

CO_2 emission was measured in the year 2014 and 2003, respectively. Moreover, CO_2 emission from furnace oil was increased 3 times in 2015 in compare to 2003 (Fig. 3d). It is interesting to note that total CO_2 emissions from Chinese road vehicles are estimated to be 148000000 million tons in 1997 and 230000000 Gg in 2002, an increase of 55% in five years as national total oil consumption on road transport system increased from 23 to 32% (Hea *et al*., 2005).

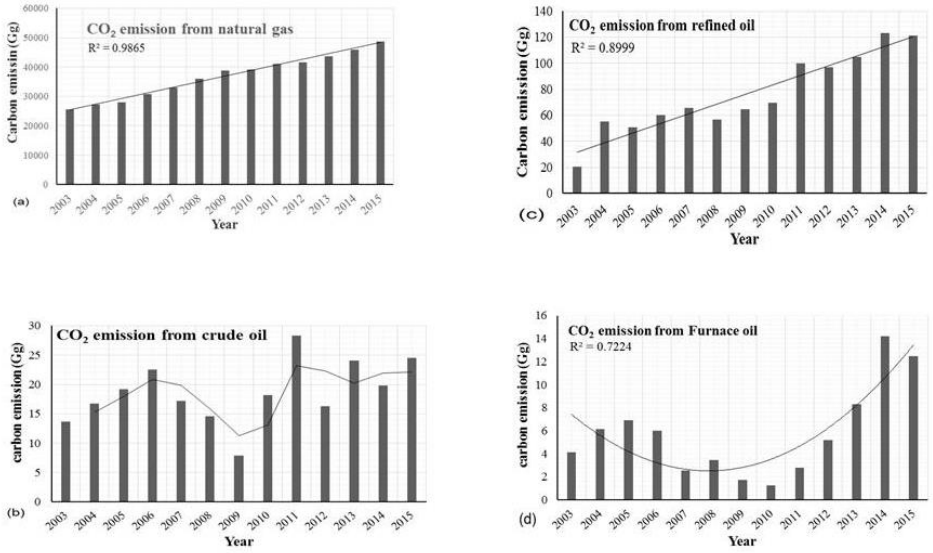

Fig. 3. Trends of CO_2emissionfrom (a) natural gas, (b) crude oil, (c) refined oil and (d) furnace oil.

CH_4 emission trends from fossil fuels consumption

The CH_4 emission from natural gas ranged from 0.04 Gg to 0.07 Gg by the study time of 2003 to 2015 and during this time highest and lowest CH_4 emission was calculated by the year 2015 and 2003, respectively. Moreover, CH_4 emission from natural has been doubled by the 12 years of observation with an enhanced consumption of natural from the base year 2003 (Fig. 2 and 4a). The CH_4 and CO_2 emission from crude oil showed similar trends (Fig. 3b and 4b). During the study, the lowest CH_4 emission from crude oil was observed in 2009, and the highest emission CH_4 from the same fuel was measured in the year 2011.

However, average CH_4 emission from the crude oil has been increased 1.19 times by the last six years and those of the last seven years (Fig. 4b). Similarly, CH_4 emission from refined oil ranged from 0.006 Gg to 0.018Gg during the study. From this fuel, CH_4 emission has been sharply increased from the year 2003 to 2015. As shown in Fig. 4c, CH_4 emission from the base year to final year has increased by 4 times. However, CH_4 emission from furnace oil showed decreasing trends for the first 7 years, after that CH_4 emission has shown increasing trends from the year 2010 to 2015. The CH_4 emission

from furnace oil may be increased by the last five years due to their enhanced consumption for energy production.

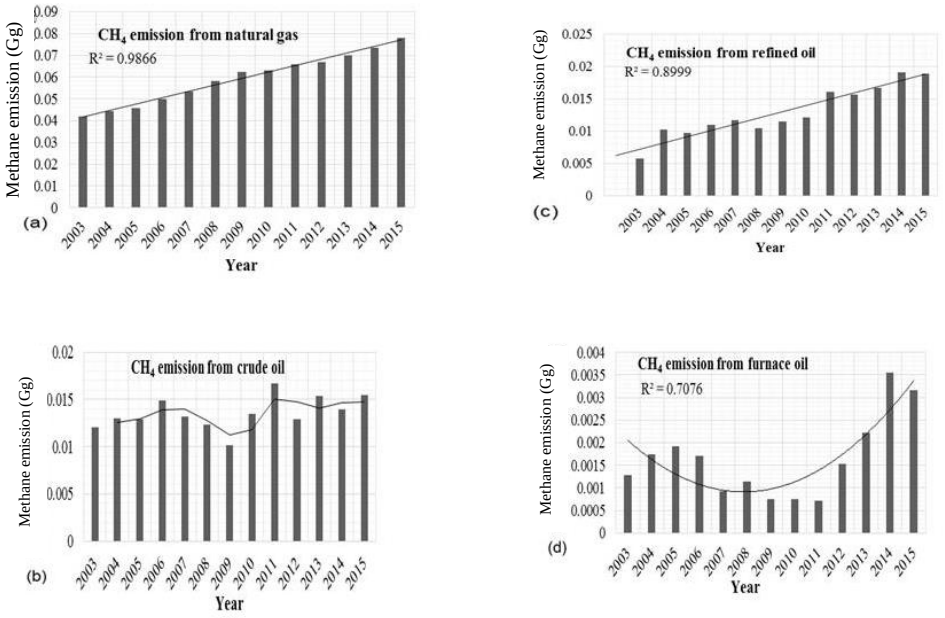

Fig. 4. CH_4 emission from combustion of (a) natural gas, (b) crude oil, (c) refined oil and (d) furnace oil.

N_2O emission from fossil fuel

During the observation period (2003-2015), total N_2O emission from fossil fuel consumption ranged from 0.019Gg to 0.030 Gg. During the observation period (2003 - 2015), highest (0.0067 Gg) emitted from natural gas combustion followed by furnace oil (0.0033Gg), crude oil (0.0032 Gg), refined oil (0.0016 Gg), respectively. In comparison to India, total amount of N_2O from fossil fuel consumption for the year 1990-1995 range from 0.2-0.3x10^3Gg having annual growth rate of 3.3% (Garget *et al*., 2012). As shown in Fig. 5a and 5c, N_2O emission from natural gas and refined oil showed a significant increasing trend. This situation may happen due to availability and large consumption of natural gas and refined oil during the study period (Fig. 5a, c and 2).

However, N_2O emission from crude oil does not show any significant increasing trend. Highest N_2O emission (0.0067 Gg) from natural gas was detected in 2015. Interestingly, at the same time, natural gas consumption also detected as the highest level (Fig. 2 and 5a). However, N_2O emission from furnace oil showed a similar trend that of CH_4 emission from the same fuel (Fig. 4d and 5d). Interestingly, at the same period (2009-2015), when N_2O emission showed increasing trends, consumption of furnace oil has also been increased (Fig. 2). These findings confirm that enhanced N_2O emissions from the year 2009 to 2015 are associated with elevated consumption of furnace oil during this period.

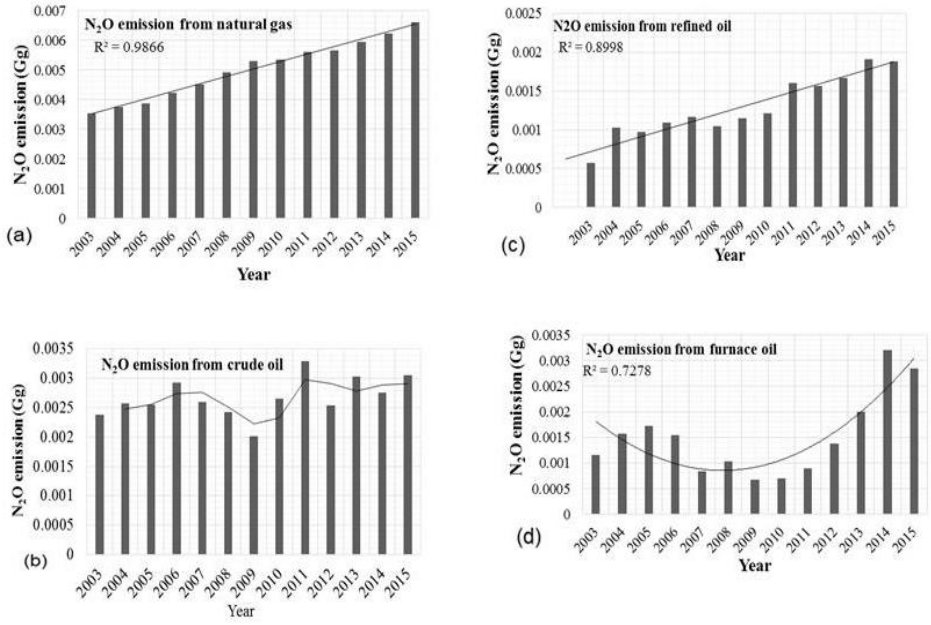

Fig. 5. N_2O emission from combustion of (a) natural gas, (b) crude oil (c) refined oil and (d) furnace oil

Conclusion

In this study, the fossil fuels consumption data of natural gas, crude oil, refined oil, and furnace oil were collected from Bangladesh statistical yearbook for the year 2003 to 2015. Therefore, from these fossil fuels consumption data, emission of CO_2, N_2O, and CH_4 was estimated for each year by using IPCC general and modified guideline. The CH_4 emission from refined oil ranged from 0.006 Gg to 0.018 Gg during the study period. It was found that the CH_4 emission from refined oil was sharply from the year 2003-2015. However, CH_4 emission from the base year to final year was increased by 4 times.

In contrast, CH_4 emission from furnace oil showed decreasing trends for the first 7 years, after that CH_4 emission was showed increasing trends from the year 2010 to 2015. This result indicates that CH_4 emission from furnace oil may be increased by the last five years due to their enhanced consumption for energy production by the recent years. It was investigated that the highest N_2O emission (0.0067 Gg) from natural gas was detected in 2015. Interestingly, at the same time, natural gas consumption also detected as the highest level. However, N_2O emission from furnace oil showed a similar trend that of CH_4 emission from the same fuel. Interestingly, at the same study period 2009 to 2015, when N_2O emission showed increasing trends, consumption data for furnace oil was also increased. These findings may confirm that enhanced N_2O emissions from the year 2009 to 2015 were associated with elevated consumption of furnace oil during this period.

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