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AN ANALYSIS OF SECTORIAL EMISSIONS, STATUS AND IMPACTS OF SHORT-LIVED CLIMATE POLLUTANTS IN BANGLADESH

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Abstract: This paper was aimed to focus on the situation and the source of short-lived climate pollutants (SLCPs) in the atmosphere of Bangladesh and their impact on the environment and health. The study used a qualitative research methodology and a review of the relevant literature to fulfill the objectives. The study showed that SLCPs were the most important air pollutants and responsible for reducing crop yields. These also had significant adverse impacts on health, agriculture and climate. The black carbon (BC) and the ozone caused adverse health impacts, which are likely leading to premature deaths in Bangladesh. The SLCPs may have direct adverse impacts on the economy, health, agriculture production, ecosystems, biodiversity, and climate change. Strategic measures should be undertaken to reduce and mitigate the SLCPs in the atmosphere of Bangladesh. Therefore, several necessary steps including introducing clean-burning biomass stoves for cooking, encouraging diesel to CNG conversion vehicles, replacing traditional brick kilns with modern technologies, and stopping the burning of agricultural residue are recommended.

Key words: Short-lived Climate Pollutants, Black Carbon, Methane, Climate Change, Emission.

INTRODUCTION

To harness the issue of climate change in Bangladesh, tackling and reducing the Short-lived Climate pollutants (SLCPs) is an important and crucial step. These agents have a relatively short lifetime in the atmosphere - a few days to a few decades - and a warming influence on climate change. There are four types of pollutants: black carbon (BC); methane (CH_4); tropospheric Ozone (O_3); and some hydrofluorocarbons (HFCs). Climate is simply the weather that is dominant or normal in a particular region while the term climate includes temperature, rainfall, and wind patterns. The SLCPs are a new concept and terminology used in the world which is referred since 2012 (CCAC, 2012).

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Recently, SLCPs has drawn much attention due to their impact on both air quality and climate (UNEP 2011, USEPA 2012). The Climate and Clean Air Coalition (CCAC) to Reduce SLCPs was launched by the United Nations Environment Programme and six countries i.e., Bangladesh, Canada, Ghana, Mexico, Sweden, and the United States on 16 February 2012. Little studies are available on the SLCPs, these are related to the other climate pollutants. These studies have been started over the decades on climate change impact, adaptation, and mitigation issues. These have been published in different journals, websites, reports, and other sources to provide knowledge, practice, and build aware people about its science, general concept, and impact of SLCPs. In Bangladesh, the Department of Environment (DoE) under the Ministry of Environment, Forest and Climate Change (MoEFCC) and International Organizations, like, UN Environment (UNEP) and CCAC have been carried out these studies but the country-wise elaborate research works were not conducted. Bangladesh government and some other organizations have pursued the studies and taken action to reduce the SLCPs in Bangladesh (CCAC 2012). But, later on in 2013, the DoE was played the pioneer organization to take practical action to conduct a study and design an action plan to reduce the impacts of SLCPs in Bangladesh. Traditionally in Bangladesh, the major sources of BC are biomass cookstoves, traditional brick kilns, open burning of municipal solid wastes (MSW), diesel driven transport vehicles, traditional rice parboilers, crop residue burning, forest fires, agriculture open burning, some industrial facilities, re-suspended dust from construction activities, roads, metal smelting, and cement factories. These have been collectively contributed more than 50 thousand metric tonnes soot in 2010 and it has a warming impact on climate 460-1500 times stronger than CO_2 (Bangladesh National Action Plan for Reducing SLCLs 2014). On the other hand, domestic wastewater, livestock enteric fermentation and manure management, flooded rice cultivation, MSW in landfills, and gas transmission and distribution are identified as the main sources of CH_4 emission that emitted about 2,500 thousand metric tonnes of CH_4 in 2010 (Bangladesh National Action Plan for Reducing SLCLs, 2018). The tropospheric ozone (O_3) and some hydrofluorocarbons (HFCs) were responsible for emissions of global warming, these are the most important contributors in Bangladesh and affect CO_2. The HFCs has created to replace ozone-depleting chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs). The emission associated with SLCPs is being harming millions of people around the world through their direct and indirect impacts on human health, agriculture and crop production, ecosystems, biodiversity, and global and regional climate. All SLCPs, including black carbon, ozone, methane, and hydro-fluorocarbons have regional and global climate impacts. The particulate matter (PM) is the major pollutant that has the subapical health concern in globally include Bangladesh. In this context, this study was focused on the nature and impact of SLCPs in the atmosphere. Additionally, the study also identified the key sectors that produce major portion of SLCPs existent in the air that are being affected the air quality in Bangladesh. However, this study was conducted to explore an implementing strategies and action plans to reduce the SLCPs in the atmosphere of Bangladesh.

MATERIAL AND METHODS

This study was descriptive qualitative research that includes surveys, interviews, and relevant literature reviews. For this, appropriate methodology helped the researcher to collect, valid and reliable data and to analyze the information properly in order to achieve a correct conclusion. For the development and collection of the data, the study was based on both primary and secondary sources. However, in this study, we were focused and analyzed only Black Carbon (BC) and Methane (CH_4) emissions of major SLCPs. Hence, these also be facilitated to develop and identify the major sources of short-lived climate pollutants (SLCPs) in Bangladesh.

To assess the effectiveness of SLCP mitigation measures and analysis for Bangladesh, a baseline scenario of Black Carbon and Methane was established using Long-range Energy Alternatives Planning and Integrated Benefits Calculator (LEAP-IBS) SLCP-NAP (national action Plan) toolkits or software developed by Stockholm Environment Institute (SEI) and Community for Energy environment & Development (COMMEND). This was an integrated planning tool to assess greenhouse gases, short-lived climate pollutants (SLCPs), and other air pollutant emissions; build mitigation scenarios; and understand how emission reductions benefit the climate, health, and crops (SEI 2017). This SLCP LEAP-IBC toolkit was mainly designed to assess a country's current and likely future emissions of SLCPs (co-emitted pollutants) and their impacts on human health, crop yields, and radiative forcing. A suitable analytical tool was developed by the Stockholm Environment Institute (SEI), the Long-range Energy Alternatives, Planning Air Pollution, Climate Impact Assessment, Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE). Besides, LEAP-IBC was an emissions estimation and scenario tool which has a specific application based on SEI's LEAP system that enables a country to compile national inventories of anthropogenic emissions of BC, CH_4, the precursors of ozone (CO, NO_x, NMVOC, and CH_4). Moreover, for primary data collection, the questionnaires were developed and contacted with several organizations that are basically involved and deal with emissions of methane and black carbon. The

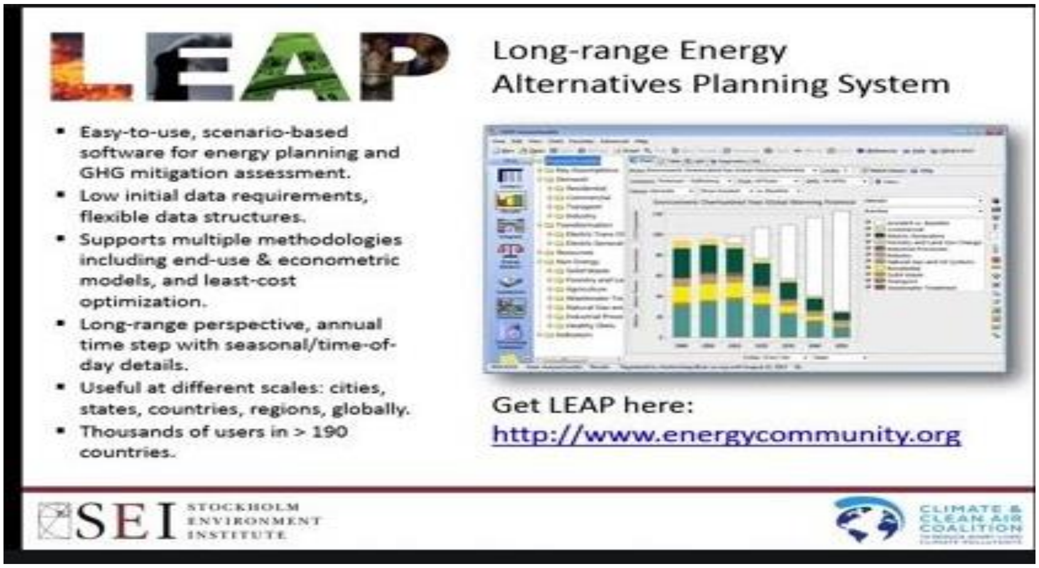

Fig. 1. Illustration of Long-range Energy Alternatives Planning System (LEAP). (Source: CCAC, 2017)

collected data from these organizations were analyzed using LEAP-IBC tool-kits. The consulted and interviewed organizations were: Bangladesh University of Engineering and Technology (BUET), Bangladesh Rice Research Institute(BRRI), Bangladesh Agriculture Institute (BARI), International Rice Research Institute (IRRI), Department of Environment (DoE), Global Alliance for Clean Cookstoves (GACC), German Development Cooperation (GIZ), Department of Agriculture Extension (DAE), Department of Livestock Services (DLS), Bangladesh Livestock Research Institute (BLRI), Bangladesh Road and Transport Corporation (BRTA), PETROBANGLA, Dhaka Water Supply, and Sewerage Authority (DWASA), Dhaka North City Corporation (DNCC), Dhaka South City Corporation (DSCC), etc. For validation of the finding, several consultative workshops were organized.

RESULTS AND DISCUSSION

The short-lived climate pollutants were black carbon (BC), methane (CH4), tropospheric ozone (O_3), and hydrofluorocarbons (HFCs); these were the most important contributors to the man-made global greenhouse effect after carbon dioxide, responsible for up to 45% of current global warming. If no action is taken to reduce emissions of these pollutants in the coming decades, these are expected to account for as much as half of the warming caused by human activity (CCAC 2012). This paper was only focused on Black Carbon (BC) and Methane (CH_4) as a component of SLCPs though it is being discussed on the emissions and impacts of Hydrofluorocarbons (HFCs) and Ozone (O_3) in general as a part of SLCPs. The most common types of Short-Lived Climate Pollutants were mainly, Black Carbon (BC), Methane (CH_4), Hydrofluorocarbons (HFCs), and Tropospheric Ozone (O_3). But this paper has discussed and analyzed the results-oriented issues, strategies, and sources of only the Black Carbon (BC) and Methane (CH_4) pollutants.

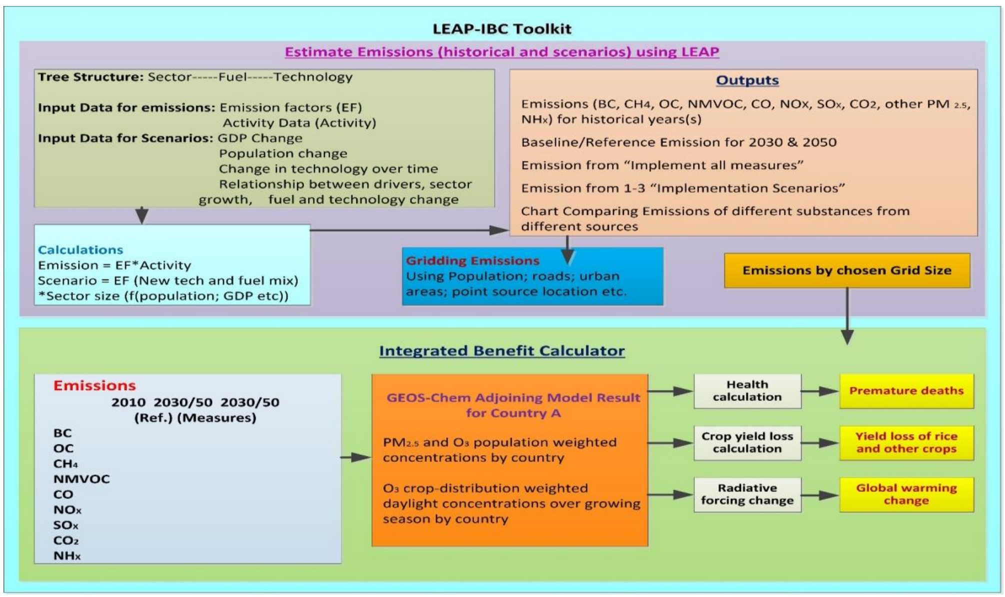

Fig. 2. Outline of the LEAP-IBC Toolkit used in the planning document and report (Source: CCAC: LEAP-IBC, 2017)

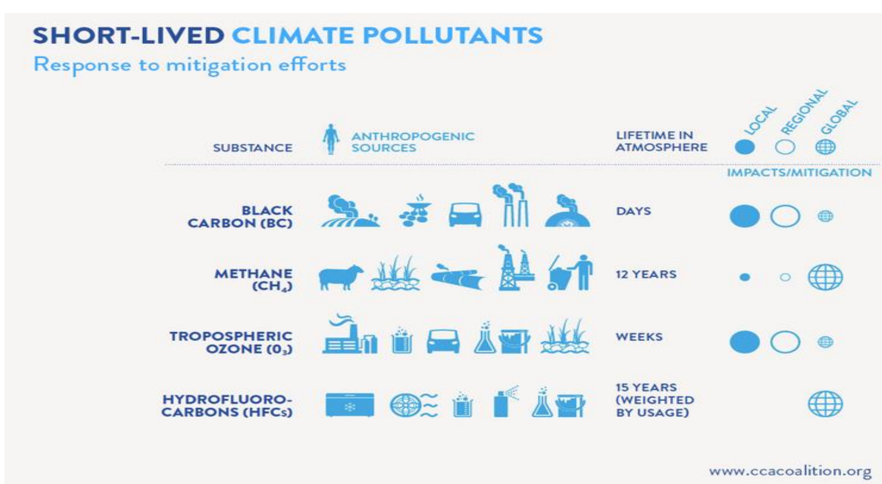

Fig. 3. Sources of emissions and duration of SLCPs (Source: CCAC, 2012)

The Sources of Black Carbon and Impact Analysis: This study indicated that traditional cookstoves, traditional brick kilns, transport particularly diesel vehicles and rice parboiling units and municipal solid waste incineration were the major sources of black carbon (BC) in Bangladesh. In addition, field burning of agricultural residues was also responsible for BC emission. The study also showed that the major sources of the particulate emissions in Bangladesh were motor vehicles (especially the ones run by diesel), biomass burning (especially in rural areas), re-suspended dust (from activities related to the construction of buildings, roads etc.), metal smelting and cement factories; which has been confirmed by Bangladesh Atomic Energy Commission and Department of Environment in studies based on particulate matter (PM) samples. The traditional cookstoves are primarily responsible for BC emissions in the residential sector of Bangladesh, about 90% of people has been used biomass fuels for cooking (GACC 2017).

In Bangladesh, annual household biomass including fuelwood consumption is 44 million tons which is 79% of the country's total biomass consumption (MoPEMR 2015). According to GACC (2017), estimation using the Fuel Analysis, Comparison & Integration Tool (FACIT), in Bangladesh, current fuel use proportions are 45.9% for firewood, 35.9% for crop residues, 8.3% for dung, 7.8% for natural gas, and only 1% for LPG in the year 2015. Traditional cookstoves are mainly responsible for Household Air Pollution (HAP) affecting 138 million people in Bangladesh and causing 78,000 premature deaths on an annual basis within the country (GACC 2017). As per the present estimation, traditional cookstoves are responsible for more than 38% of the total BC emission, which was about 19,500 metric tons in the year 2010.

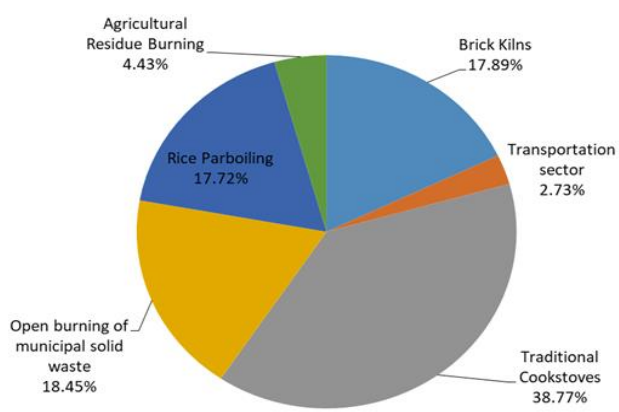

Fig. 4. Contribution of Different sources to BC Emissions in the base year 2019, (Source: GACC, 2017)

Industrial sector: Brick Kiln: The construction sector has been growing at a rate of 8.1% to 8.9% in a year during the last decade, with concomitant growth in demand for bricks (IIDFCL 2009), and now the industrial sector, brick kilns are the most dominant source of air pollution because brick is the main construction material in the country. Brick production has also been identified as an important area where a substantial reduction of BC emissions be achieved. A total of 6,637 brick kilns (this is now more than this (Table1) exist in the country; among them, 2,602 are fixed chimney, 4,045 are zigzag, 73 are Hybrid Hoffman and 41 kilns are using automatic/tunnel technology (DoE 2016). Total brick production in Bangladesh is estimated at 17.2 billion per year

Fig. 5. Emission of BC from Brick Kiln. (Source: Internet)

which emitted 9.8 Mt of CO_2. Approximately 3.5 metric tonnes of coal and 1.9 metric tons of firewood were consumed against this production. (World Bank 2011). From the BC sector, the contribution from brick kilns is estimated to be 18% in 2010, which amounts to 9 thousand metric tons. The contribution is expected to increase three times by 2030 and seven times by 2050. Conversion of traditional kilns to improved kilns can avoid more than 2,600 premature deaths. On analysis and based on the results and discussion, the major barriers and weakness is not to be regular monitoring and controlling mechanism are followed to reduce emissions of black carbon from traditional brick kilns were insufficient by the government but government-initiated that about 63% of total brick kilns have already been converted to environment-friendly kilns during the last few years due to enforcement of “The Brick Manufacturing and Brick Kilns Establishment.

Industrial sector: Traditional Rice Parboiling: Mills (*Chatal Mills*) typically run at low thermal efficiency (15-30%), use rice husk as fuel, which is a major source of PM and BC. More than 34 million metric tons rice was produced in Bangladesh (BBS 2016) and the staple amount (90%) of rice is cooked in small or medium-sized rice parboilers at the mill sites (GIZ 2012). Currently, there are around 30,000 rice mills in Bangladesh. Among them, more than 17,000 are enlisted at Bangladesh Auto and Major Husking Millers' Association and they have '*Chatal*s' or space for sun drying, while others have no *Chatals*. Farmers use these rice mills for milling purposes only and they parboil rice on their own. Around 23,700,000 metric tons/year are parboiled through the traditional rice parboiling system (*Chatal*) and only 114,000 metric ton/year rice is parboiled through improved parboiling units (GIZ 2017). In Bangladesh, the annual estimated energy demand for rice food grain processing has been calculated to be 40.5, 50.3, and 77.8 million GJ for the years 2000, 010, and 2030 respectively (Ahiduzzaman and Islam 2009). It was reported that CO_2 emissions from rice processing varied from 938.2 kg to 1,360.0 kg for a metric ton of finished rice (Roy *et al.* 2008). Traditional rice parboilers emitted more than 17% (8.91 thousand metric tons) of total sectoral BC in 2010 which is expected to remain unchanged up to 2050. Technological improvement of rice parboilers is estimated to avoid about 230 premature deaths annually by the year 2050. On analysis and based on the results and discussion, the major barriers and weaknesses were found to reduce emissions of black carbon from traditional rice parboiling, and lack of awareness building to eliminate open-burning of agricultural residue.

Table 1. Estimated BC Emissions from different sources and their projections (Source: SLCP National Action Plan Report DOE, 2018).

BC Sources	**BC Emissions (thousand metric ton) in different years**			
	2010	2020	2030	2040
Traditional Cookstoves	19.50	21.76	23.79	25.16
Open burning of municipal solid waste	9.28	10.43	11.41	12.07
Brick Kilns	9.00	16.65	24.30	44.95
Rice Parboiling	8.91	8.91	8.91	8.91
Agricultural Residue Burning	2.23	2.23	2.23	2.23
Transportation sector	1.37	2.52	3.67	6.73
Total	**50.29**	**62.50**	**74.30**	**100.05**

Open-burning of Agricultural Residue: Crop harvesting and residue management are done manually in Bangladesh. A survey conducted over 600 rice plots show that complete field burning was practiced in only 3% of the plots, while 38% of the plots practiced 'upper part metric ton rice residue was burnt in the eleven districts of the region in 2005 and about 3.14 million metric tonne rice removal and lower part field burning. According to the estimates of a recent study, approximately 0.02 million residue countrywide in the year 2010 (Haider 2013). This burning generally takes place during the winter after a crop harvest. A study by Haider (2013) establishes that farmers may be willing to stop rice residue burning if they were offered compensation of Tk 3,240-3,353 per acre. Sectoral contribution by crop residue burning is estimated at 4.35%, which amounts to 2.23 thousand metric tons of BC. Open burning of waste at both the

Fig. 6. Traditional Rice Parboiling Units Emitting Heavy Smoke. (Source: Internet)

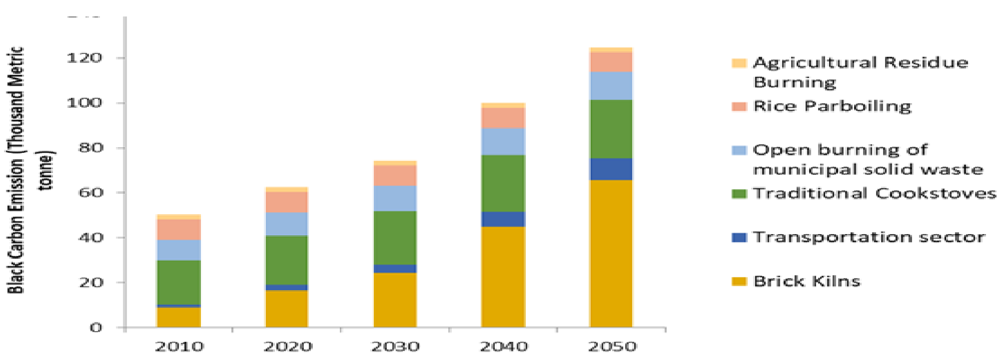

Fig. 7. Estimated BC Emissions from Different Sources and their projections ((Source: SLCP National Action Plan Report, DoE 2018).

residential level and at dumpsites produces many atmospheric pollutants, including greenhouse gases (GHGs), reactive trace gases, particulate matter (PM), and toxic compounds

Transportation and Diesel Motor Vehicles: Major vehicles are emissions of BC emission, especially in a metropolitan city. The transportation sector in

Bangladesh uses a large quantity of petroleum and diesel oils. Vehicle numbers are increasing significantly day by day. As of March 2017, according to BRTA, the total number of registered land vehicles in Bangladesh was 2,984,213; in 2010 the number was about half this. At present approximately 14,000 vehicles are using diesel as their fuel. Transport vehicles contribute 2.73 % of BC. Diesel-driven vehicles are majorly responsible for creating the total particulate emissions even though the number of buses, minibuses, and trucks is smaller in comparison to the personal vehicle fleet. It was estimated that in the year 2010 approximately 6,035 tonnes PM_{10} and 4,288 tonnes $PM_{2.5}$ were emitted from vehicular sources within and around Dhaka (Afrin 2012). Monthly Air quality Monitoring under CASE Project of DoE found 46.1 and 55.9μg/m^3 $PM_{2.5}$ concentration in two locations of Dhaka city in April 2017 whereas at the same time the concentrations were 54.4, 52.0, 43.3, 38.9, 45.8 and 41.3μg/m^3 in Gazipur, Narayanganj, Chittagong Sylhet, Khulna Rajshahi and Barishal.

Fig. 8. Emission of BC by Diesel Drive Vehicles. (Source: Internet)

Table 2. PM and BC concentrations in major cities in Bangladesh during 2010-2012 Solid Waste and Open Burring in Cities. (Source: SLCP National Action Plan Report DOE, 2018)

Parameter	Rajshahi			Dhaka			Khulna			Chittagong		
	Concentration (μg/m^3)											
	PM_{10}	$PM_{2.5}$	BC	PM_{10}	$PM_{2.5}$	BC	PM_{10}	$PM_{2.5}$	BC	PM_{10}	$PM_{2.5}$	BC
Min	24.3	14.9	3.07	21.1	14.3	1.05	10.3	6.2	1.44	13.2	9.34	0.84
Max	1526	842	46.1	419	212	17.2	579	371	23	345	211	11.4
Mean	244	155	131	130	65.1	7.20	112	64.7	5.84	117	73.3	4.32
STD	172	112	7.05	74.2	41.2	3.31	88.4	56.8	3.58	78.5	50.7	2.67

Solid waste and open burning are generating about 8,000 metric tonnes of solid waste each day from the six major cities (Dhaka, Chittagong, Khulna, Rajshahi, Barisal, and Sylhet), of which, Dhaka city alone is contributing about 70% (Anwarul and Jahiruddin 2015) which is one of the major sources of BC emissions. Since there are no municipal solid waste incineration facilities in Bangladesh, a huge fraction of the uncollected waste is burnt openly contributing to BC emissions. As per Waste Atlas, the annual waste generation rate in Bangladesh is 149.7 kg $person^{-1}$ $yr^{-1,}$ and the total municipal waste generation rate is 22,528,901 tonne $year^{-1}$, of which, only 20% of waste is under collection coverage, while the remaining waste is disposed of in of an unsound manner. The waste generation showed an increasing trend from 1.04 million tonnes per year to 6.6 million tonnes per year from the year 2000 to 2050 under the compound annual growth rate approach in Dhaka city. The associated GHGs emission from untreated MSW also increased gradually from 0.86 million tonnes CO_2 equivalent to 5.5 million tonnes CO_2 equivalent. Similarly, GHGs emissions from untreated MSW in Chittagong city showed a gradually increasing trend from 0.18 million tonnes CO_2 equivalent to 2.9 million tonnes CO_2 equivalent, with the increasing waste generation from 0.23 million tonnes to 3.6 million tonnes under the CAGR approach from the year 2000 to 2050. In Dhaka city, from the generated MSW estimated 1.18 million tonnes and 1.4 million tonnes of CO_2 equivalent were emitted in 2010 and 2015, respectively, and projected to generate 2.8 million tonnes of CO_2 equivalent by 2030 and 5.5 million tonnes of CO_2 equivalent by 2050 (Nazmul 2016).

Fig. 9. Emission of BC during Solid Waste and Open Burning. (Source: Internet)

Table 3: Projection of waste generation scenario in Urban Areas of Bangladesh. (Source: SLCP National Action Plan Report DOE, 2018)

Year	Urban Population	% of total Population	Waste Generation Rate (kg/capita/day)	Total Waste Generation (metric ton/day)
1991	20,872,204	20.15	0.49	9,873.50
2001	28,808,477	23.39	0.50	11,695.00
2004	32,765,152	25.08	0.50	16,382.00
2015	54,983,919	34.20	0.50	27,492.00
2025	78,440,000	40.00	0.60	47,064.00

Sources, Emissions, and Impacts Analysis of Methane: The major activities generating CH_4 in Bangladesh are flooded rice cultivation, livestock farming (enteric fermentation and manure management), domestic wastewater treatment, and MSW landfills. Using the LEAP toolkit, the contribution of CH_4 from different sectors was estimated taking into account the current activity rates and emission scenarios. In 2010 total emissions of CH_4 were 2,491 thousand metric tons. The largest source of CH_4 was domestic wastewater with 823 thousand metric tons; representing 33.05% of the total CH_4 emissions. The second highest CH_4 contributor is the livestock sector (enteric fermentation and manure) which generates 649 thousand metric tons (26.05%) of CH_4 while flooded rice cultivation contributed 23.86% (595 thousand metric tons); landfill contributed 6.07% (151 thousand metric tons); fugitive emissions from natural gas production and distribution contributed 3.48% (87 thousand metric ton) while other sources contributed 7.48% to the national CH_4 inventory. Emissions were from industrial sources, brick kilns, transport, residential lighting, and cooking.

Continuously flooded rice fields are the major source of the increased level of atmospheric CH_4. In Bangladesh, about 11.53 million ha area was under rice cultivation in the year 2010-11 which stands at about 11.42 million ha in 2014-15 (BBS, 2016). The total irrigated area of Bangladesh has been increasing each year and is responsible for CH_4 emission in Bangladesh. The Total Irrigated area of the country was 7.13 and 7.41 million ha in the years 2012-13 and 2014-15 respectively (BBS 2016). The Inventory of GHG emissions from the agricultural sector prepared for the TNC estimated the total CH_4 emission from rice cultivation to be about 543.31 Gg in 2006 and 603.55 Gg in 2012 (Hussain and Rashid, 2016). The Intergovernmental Panel on Climate Change (IPCC, 1996) estimated the global emission rate from paddy fields at 60 Tg/yr, with a range of 20 to 100 Tg/yr. This is about 5-20 percent of the total emission from all anthropogenic sources.

Livestock Enteric Fermentation: Livestock is a significant contributor to global CH_4 emissions which is mainly confined to enteric fermentation and manure management. CH_4 emission from the livestock and poultry sector of Bangladesh has been estimated to be 649 thousand metric tonnes in 2010, and this would increase to more than 2,100 thousand metric tonnes by 2050. In 2010 the sectoral contribution of CH_4 emission by the livestock sector was the second largest at 26%. It has been reported in the inventory prepared for GHG emission from the agricultural sector for the Third National Communication that the total estimated CH_4 emission from the livestock sector in 2010 was 643.4 Gg of which enteric CH_4 emission was about 522.57 Gg. CH_4 emission from this sector is increasing and the average CH_4 emission incretion rate was 1.34% during the 2006 to 2012 period due to the increase of livestock population (Hussain and Rashid 2016).

Livestock-Manure Management: The substantial growth of the cattle and poultry population caused a huge amount of CH4 emission. In Bangladesh, annually about 151.3 and 4.52 million metric tonnes of manure was produced in 2010-11 respectively (MoFL, 2015). This methane emission was due to the lack of management practice among the livestock owners. Manure management is the major option to mitigate CH_4 emissions from livestock because little can be done to mitigate CH_4 emissions from enteric fermentation. Generation of biogas from cattle and poultry manure using anaerobic digestion is a good option.

Fig. 10. Flooded Rice Cultivation as major source of CH_4 Emission in Bangladesh (Source: Internet)

Emission from the Waste Water: Wastewater is the most dominant source of CH_4 emission, accounting for about 39% of the estimated total CH_4 (DoE 2014). Usually, wastewater and septic tank/soakage pit overflows and falls into low-lying areas, lakes, *Khals* (Canals), and rivers within and surrounding the urban centers. Apart from causing severe pollution wastewater and sludge accumulated in these water bodies undergo anaerobic decomposition producing CH_4 and a range of other foul gases. According to the second national communication to UNFCC (GoB/ UNDP, 2012), the major sources of methane emissions include domestic wastewater, livestock, paddy, poultry, and solid waste. Estimated methane emissions from these sources for the year 2004-05 are 621.08 Gg, 493.16 Gg, 380.75 Gg, 84.79 Gg, and 16.50 Gg, respectively. In other words, wastewater is the most dominant source of methane emission, accounting for about 39% of estimated total methane emission; while solid waste account for about 1% of the total emission. About 13,332 tonnes of solid waste is generated each day in the urban areas of Bangladesh, and with the rapid growth of the urban population, the waste generated can go up to 47,064 tons/day within 10-15 years from now (World Bank 1999). Domestic wastewater is responsible for 33% of the total sectoral CH_4, which was about 823 thousand metric tonnes in 2010 and this amount is predicted to be 1,012 and 1,097 thousand metric tonnes by 2030 and 2050 respectively. Increased generation of methane (CH_4) from municipal solid wastes (MSW) alarms the world to take proper initiative for the sustainable management of MSW, because it is 34 times stronger than carbon dioxide (CO_2).

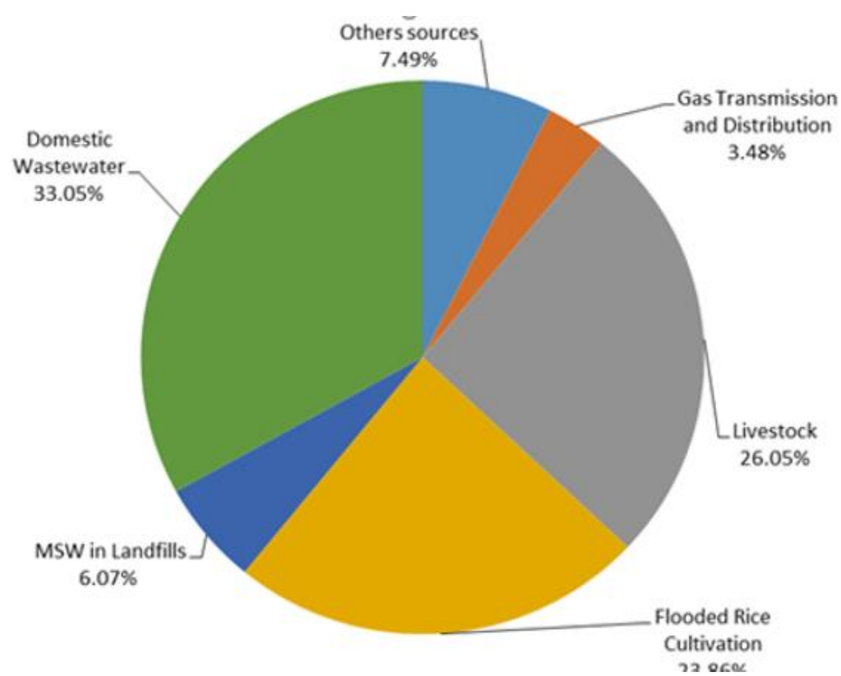

Fig. 11. Contribution of Different Sources to CH_4 Emission in the Base Year 2010 (Estimated using LEAP Toolkit). (Source: CCAC 2017)

Fugitive Emission from Gas Fields and Transmission Lines: Emission from gas fields and transmission lines is another source of CH_4 emission in Bangladesh. The country currently has 22 gas fields with total gas production of 892.17 billion cubic feet (BCF) in FY 2014-15 (Petrobangla 2015). Up to the end of 2017, Petrobangla has established 2,550 km transmission lines, 2,372 km distribution lines, 213 km lateral lines, and more than 16,600 km feeder and service lines all over the country. There is virtually no data on the emission/leakage of CH_4 from gas production and processing. On the other hand, about 0.667 million metric tonnes of coal were produced in 2010-11 and the production was raised to 1.022 million metric tonnes in 2015-16. These coal mines contain 6.51 to 12.68 m^3/t Coal Bed Methane (CBM) depending on the coal seam estimated by Islam and Hayashi (2008).

Impacts of the Short-Lived Climate Pollutants (SLCPs) on Atmosphere, Ecosystems, and Health: Black carbon is an important contributor to warming because it is very effective at absorbing light and heating its surroundings. Per unit of mass, black carbon has a warming impact on climate that is 460-1,500 times stronger than CO_2. Due to the increase in global warming, the IPCC report gave the world a clear deadline to avoid catastrophe: greenhouse gas emissions must be halved from their 2010 levels by 2030 to avoid reaching 1.5 °C. When suspended in the atmosphere, black carbon contributes to warming by converting incoming solar radiation to heat. It also influences cloud formation and impacts regional circulation and rainfall patterns. When deposited on ice and snow, black carbon and co-emitted particles reduce surface albedo (the ability to reflect sunlight) and heat the surface. The Arctic and glaciated regions such as the Himalayas are particularly vulnerable to melting as a consequence.

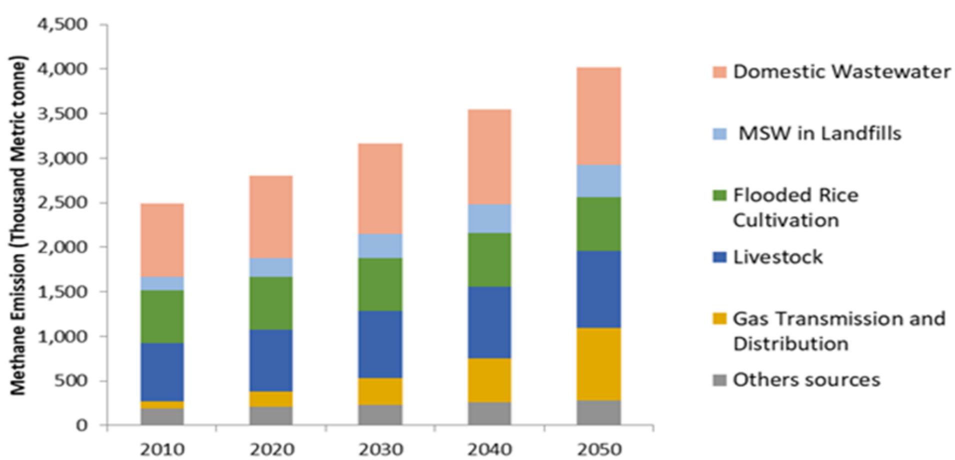

Fig.12. Estimated CH_4 Emissions from different sources and their future projection. (Source: SLCP National Action Plan Report, DOE 2018)

Black carbon and its co-pollutants are key components of fine particulate matter ($PM_{2.5}$) air pollution, the leading environmental cause of poor health and premature deaths (World Bank 2017). $PM_{2.5}$ has been linked to a number of health impacts including premature death in adults with heart and lung disease, strokes, heart attacks, chronic respiratory diseases such as bronchitis, aggravated asthma, and other cardio-respiratory symptoms. Each year, an estimated 7 million premature deaths are attributed to household and ambient (outdoor) $PM_{2.5}$ air pollution. Exposure from the open fires or inefficient fuels and cooking and heating for nearly three billion people in the developing world – causes nearly 4 million premature deaths annually, including nearly 106,900 deaths in Bangladesh, every year. Black carbon can affect the ecosystems by depositing on plant leaves and increasing their temperature, dimming sunlight that reaches the earth, modifying rainfall patterns, and changing rain patterns. Methane is a greenhouse gas with a high ability to cause warming potential. It has a direct influence on climate. But methane also has a number of indirect effects on human health, crop yields, and the quality and productivity of vegetation through its role as an important precursor to the formation of tropospheric ozone.

Major Strategies and Actions to Reduce the Short-Lived Climate Pollutants (SLCPs) in Bangladesh: Based on the discussion on the current status and major sources of the SLCPs in the atmospheric air, the authors are proposed strategies and action plan in order to reduce the emissions which are as follows. In addition, the traditional brick kiln should be replaced by the improved and modern technology of brick kilns. Similarly, the traditional home cookstoves should be replaced by environment friendly and improved home cookstoves. The rice parboiling Technology could be developed with emphasized on modern Rice Parboiling Technology to reduce the emission of black carbon. For example, GIZ developed rice parboiling, enforce to use to standard diesel oil; increase roadside inspection, identified of motorcycles and diesel vehicles. Stop older vehicle fleets, use High-S diesel, and improve vehicle maintenance, reduce the emissions from diesel-driven vehicles. While it is necessary to convert these to CNG-driven ones and it is necessary to eliminate the high-emitting vehicles, by phasing out pre-Euro engines in diesel-run vehicles. The appropriate regulations need to be formulated and passed to ban older buses and trucks, increase livestock sector activities and reduce the emission of methane. For instance, the construction of biogas plants in medium and large poultry and dairy farms and community-based plant, promotion of the use of cattle feed additives could be controlled and minimized the emissions from the livestock sector. The AWD should be introduced to reduce emissions of methane from flooded agricultural cultivation.

Therefore, it is necessary to build awareness among the farmers, reduce the emissions of methane from livestock enteric fermentation. Thus, the changing of livestock diets, construction of biogas plants in medium and large poultry and dairy farms, and community-based plants, Manure management could be the major option to mitigate CH_4 emission from livestock. In this case, little can be done to mitigate CH_4 emission from enteric fermentation. In case of waste management, the strategies and measures could be adopted to reduce the emissions such as separation and treatment of biodegradable municipal solid waste through recycling, anaerobic digestion as well as landfill gas collection with combustion/utilization, establishing/expanding sewerage system, and establishing municipal wastewater treatment plant in major urban centers, etc.

CONCLUSION

Based on the discussion and analysis in the paper, and sources and estimation of sectoral emissions, it can be stated that the major sources of BC of SLCPs emissions in Bangladesh are brick kilns, rice parboiling units, traditional home-cookers, diesel vehicles, burning of agriculture residue, solid waste in cities, etc. which are. Here only major sources are described and analyzed. Due to the constraint in availing information, the sources of BC have not been described critically and did not cover all sources of these pollutants. To estimate the SLCPs in Bangladesh, no formal research has been conducted before by any academic and research organizations. Only, DoE conducted a survey and assessment of estimation of emissions for the national action plan development in 2013 and 2017. Under this circumstance, it is necessary to address and find out the gaps and impacts on health and the environment to estimate emissions and problems to reduce the SLCPs in Bangladesh. Against this backdrop, this study will enrich the growing body of research. Our study reveals that major sources of emission of BC of the short-lived climate pollutants in Bangladesh are traditional cook-stoves mainly used in the village communities, traditional brick kilns practiced throughout the country, rice parboiling units operated by the informal traders for rice boiling purposes, burning of crop and agriculture residue for both cooking and rice parboiling purposes, diesel-driven vehicles, used old and unfit transports, open burning of solid waste in cities, open burning of crop residue, etc. Bangladesh government has targeted smoke-free kitchens (e.g. *bondhu chula*) all over the country by 2030 and 30 million inefficient traditional cookstoves will be replaced by improved cookstoves (ICS). For proper waste management, the appropriate landfilling place should be improved and developed by introducing improved technology. Besides, an effective policy and strategy regarding wastewater management should be formulated. To reduce the emissions from diesel-driven vehicles it is necessary to convert these to CNG-driven ones and it is necessary to eliminate the high-emitting vehicles, by phasing out pre-Euro engines in diesel-run vehicles; also, appropriate regulations need to be formulated and passed to ban older buses and trucks. A significant amount of CH_4 emission from rice and paddy fields can be reduced through proper water and organic material management and alternate wetting and drying (AWD) methods.

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