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Carbon Footprint Assessment in Various Industries of Gazipur District

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Abstract: Greenhouse gas (GHG) emissions are a critical concern in the textile industry. This study assesses the carbon footprint of textile industries in the Gazipur district, using data collected through field visits in 2024. Emissions from fuel combustion and electricity consumption were quantified using the IPCC Tier 1 and Tier 2 approaches, respectively, and calculated using Life Cycle Assessment (LCA) and the GHG Protocol for scope 1 and scope 2 sources. Geographic Information System (GIS) mapping was utilized to delineate the study area. Results revealed that gas combustion is the primary emission source, while diesel combustion contributes the least. The highest emission recorded was 4,343,209 kg CO_2 in 2023, and the lowest was 1,014,503 kg CO_2 from electricity in study area S2. Larger industries with higher fuel consumption had greater emissions, while smaller industries emitted less due to limited operational scope. To mitigate emissions, the study recommends techniques like gas traps, economizers, effluent gas boilers, steam line insulation, alternative fabrics, and renewable energy sources. It also highlights the potential benefits of carbon trading for cost savings and sustainability. Reducing emissions in textile industries will significantly contribute to mitigating climate change and promoting environmental sustainability in Gazipur and beyond.

Keywords: *Carbon Footprint, Greenhouse Gas, Global Warming, Energy consumption, Emission*

Introduction: Nowadays global warming" and "carbon footprint" are buzz phrases. The release of Green House Gases (GHG) is responsible for this warming of the atmosphere; the primary contributions are carbon dioxide, methane, nitrous oxide, and fluorocarbons. Greenhouse gas emissions from industries primarily come from burning fossil fuels for steam generation in boiler and captive power generation which results in climate change and global warming [1]. Industries are the third largest sectors of carbon emissions [2]. Gazipur is one of the most polluted districts with the highest greenhouse gas emission in Bangladesh. Rapid industrial development has made it a polluted area. CO_2 footprint or carbon footprint is a measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. The carbon footprint includes both direct and indirect sources of emissions. Carbon footprints are usually reported in tons of emissions (CO_2-equivalent) per unit of comparison; such as per year, person (also called per capita), kg protein, km travelled and alike. Economic development and rapid industrialization in Gazipur district during the recent years may increase climate change and global warming contribution due to higher level of carbon emission.

A high concentration of GHG affects the earth's equilibrium making it out of balance, creating a dangerous rise in temperatures and extreme weather conditions. Increasing global temperature means that ecosystems will change; some species are being forced out of their habitats because of changing conditions, while others are flourishing. Secondary effects of global warming, such as lessened snow cover, rising sea levels, and weather changes, may influence not only human activities but also the ecosystem. The increasing atmospheric carbon dioxide concentration is likely the most significant cause of the current warming [3]. The textile industry's carbon footprint could only be decreased by an organized approach that included a continual improvement process [4]. Increased energy efficiency would lead to decreased energy usage and thereby reduced GHG emissions [5]. The objectives of the study are:

- To assess the carbon footprint of the industrial area of Gazipur.
- To know the potential environmental impacts of higher carbon emission.
- To assess possible techniques for Greenhouse Gas reduction.

Materials and Methods: Carbon emission is measured following IPCC (2006) Guidelines for National Greenhouse Gas Inventories [6,7]. According to this, carbon emission is measured depending on the type of gases emitted. Most carbon is emitted as CO_2, along with a small amount emitted as CO and CH_4. From combustion sources and purchased electricity the main greenhouse gases emitted are CO_2, N_2O and CH_4. Collected data of carbon emission from fuel consumption, electricity consumption, production capacity etc. from different textile industries has also been presented in this chapter.

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Sampling Location: This study has been carried out by collecting data from 5 different industries which are located in Gazipur district. The data is collected from Knit Plus Limited (S_1), Knittex Industries Limited (S_2), Ratool Apparels Limited (S_3), Circular Fashion Industries Limited (S_4) and Versatile Textiles Limited (S_5). This study area is shown in Fig 1.

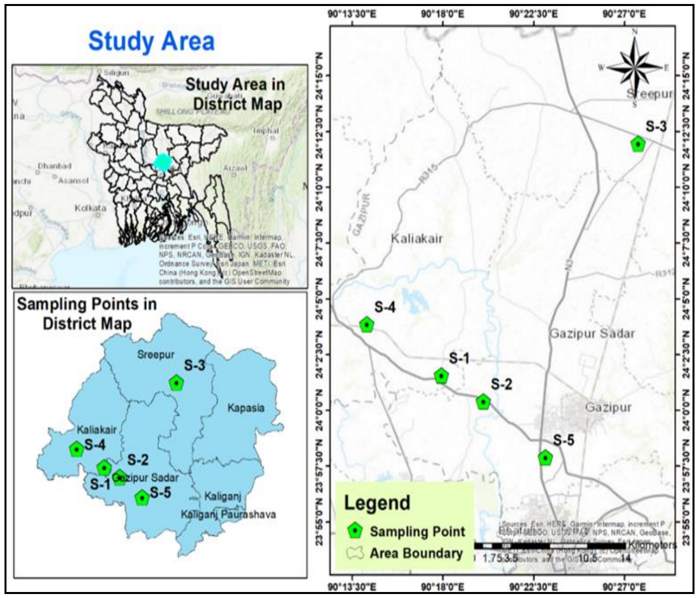


Fig. 1: Map of the Study Area (Gazipur District).

Carbon Emission Protocol: IPCC (2006) guidelines represented three tiers for carbon emission estimation:

Tier 1: This approach includes emission from all combustion sources. For every applicable direct greenhouse gas, Tier 1 emission factors are known. Emission factors for CO_2 are mostly influenced by the fuel's carbon content.

Tier 2: This technique uses an emission factor particular to each country, is applicable in the event of indirect emissions from electricity purchased.

Tier 3: This method is based on a thorough, bottom-up evaluation of emissions from specific sources.

Method: There are two standardized approaches to measuring greenhouse gas emissions across the garment sector:

Life cycle assessment; and

Greenhouse Gas Protocol accounting.

Life Cycle Assessment (LCA): In life cycle assessment (LCA) research, greenhouse gas emissions are classified as having a "global warming potential" and are expressed in kilograms of carbon dioxide equivalent (kg CO_2e). For instance, 25 kg of CO_2e is equivalent to 1 kilogram of methane [8].

Greenhouse Gas (GHG) Protocol: Here corporate Standard (2001) defines emissions under three “scopes”:

Scope 1: This is referred to as a company's direct control over greenhouse gas emissions.

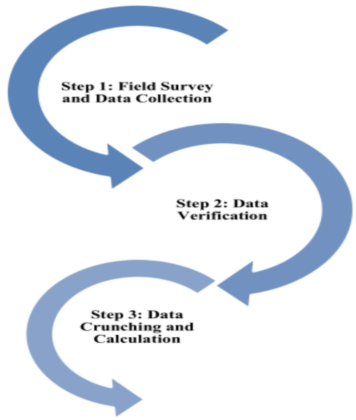
Scope 2: These are the indirect emissions brought on by the organization's acquisition and use of energy.

Scope 3: These are the emissions of greenhouse gases that an organization can affect but not directly control.

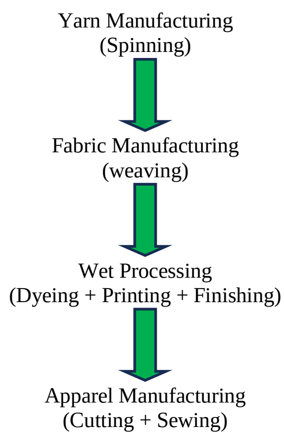
Equipment: In this study, emission has been estimated using the following equipment’s:

1. Testo 340- Flue Gas Analyzer
2. Digital Multimeter

Steps of the Study: The whole study includes 3 main steps i.e. data collection, data verification, data crunching and calculation.



Site Selection, Field Survey and Data collection: Field visits to those industries are used to gather data in order to determine the sources of CO_2 emissions. The Testo 340 Flue Gas Analyzer has been used to check emission and optimize burner efficiency. This study also made use of some secondary data, such as the fuel's net calorific value and the IPCC's 2006 guidelines for the CO_2, CH_4, and N_2O emission factors. The main production process flow in textile industries and CO_2 emission sources from these sections observed during field visit is as follows:



Data Verification: The information gathered has been validated. In order to obtain reliable information, contact has been made with plant staff to see if any data is missing or needs clarification.

Data Processing, Analysis and Interpretation (Data Crunching and Calculation): After data collection from the study area, statistical calculations have been done and recorded in a excel spreadsheet. For calculating carbon footprint, the following formula has been used'

Carbon footprint = Activity Data × Emission Factor

Here,
Activity data = the parameter that defines the level of activity that generates greenhouse gas emissions.
Emission factor = amount of greenhouse gases emitted for each activity.
CO_2 emission from the stationary combustion sources (i.e. boiler, generator) as well as indirect emission from purchased electricity have been calculated as follows:

I. Energy consumption: For calculating emissions from energy consumption (e.g., natural gas or diesel), use the following formula:
Emissions (CO_2e) = Energy consumption (in units, e.g., kg or liter) × Emission factor (for the energy source used).

II. Purchased electricity: For calculating emissions from purchased electricity use the following formula:
Emissions (CO_2e) = Energy consumption (in units, e.g., KWh or MWh) × Emission factor (grid emission factor).

Results and Discussion: The fuel burned in generators to generate electricity and in boilers to produce steam and to generate grid energy is the main source of carbon emissions in the textile industry. The present carbon emissions in this study have been calculated by data analysis, adherence to IPCC guidelines, and consulting some published publications. The energy consumption data including fuel combustion (i.e., Gas and Diesel) and electricity used obtained from different textile industries in Gazipur district and amount of carbon emission from these sources or carbon footprint values are presented graphically which shows the highest, medium and lowest emission sources.

1) Study Area S_1

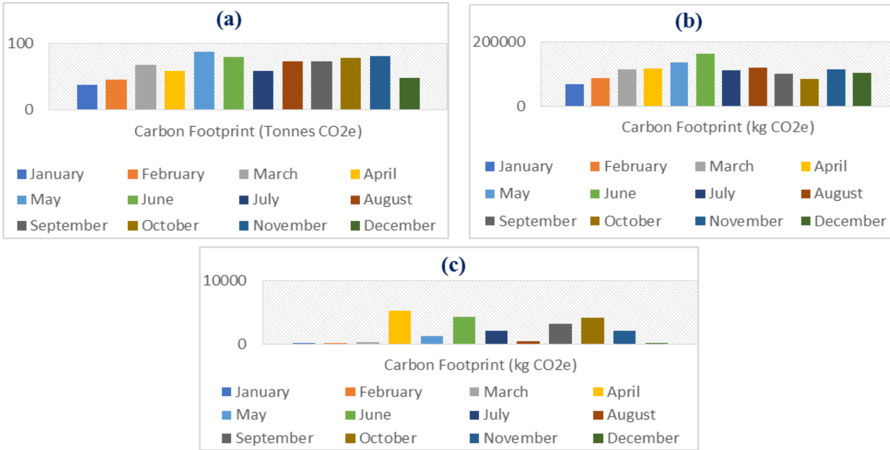


Fig. 3: Carbon emission from diesel Consumption from Study Area S_1(2023) from- a) electricity consumption, b) gas consumption, c) diesel consumption.

Carbon emission i.e. carbon footprint from different activities in S_1 can be graphically represented as below:

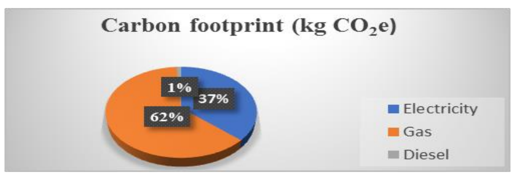


Fig. 4: Carbon footprint from S_1.

From the above figure, it is seen that gas combustion acts as the main source for carbon emission in study area S_1. Electricity consumption creates 37% carbon emission and only 1% carbon is emitted from diesel combustion. This indicates that the main contributor to air pollution and global warming through carbon emission is gas combustion which should be taken under control.

2) Study Area S_2

Table 1: Carbon emission from Study Area S_2(2023).

Month	Carbon Footprint (kg CO_2e) for electricity consumption	Carbon Footprint (kg CO_2e) for gas consumption	Carbon Footprint (kg CO_2e) for diesel consumption
January	74453.75	592836.5	4288
February	45736.21	391661.8	8576
March	66299.85	372813	6432
April	65235.89	291464	14472
May	139335.2	229820.7	36448
June	43254.53	407183.4	23584
July	53181.92	306004	19296
August	109553.7	394573	30016
September	104944.8	341255.8	25728
October	104233.9	341707.6	25192
November	104851.7	340071.7	23852
December	103421.9	333817.7	24388
Total:	**1014503**	**4343209**	**242272**

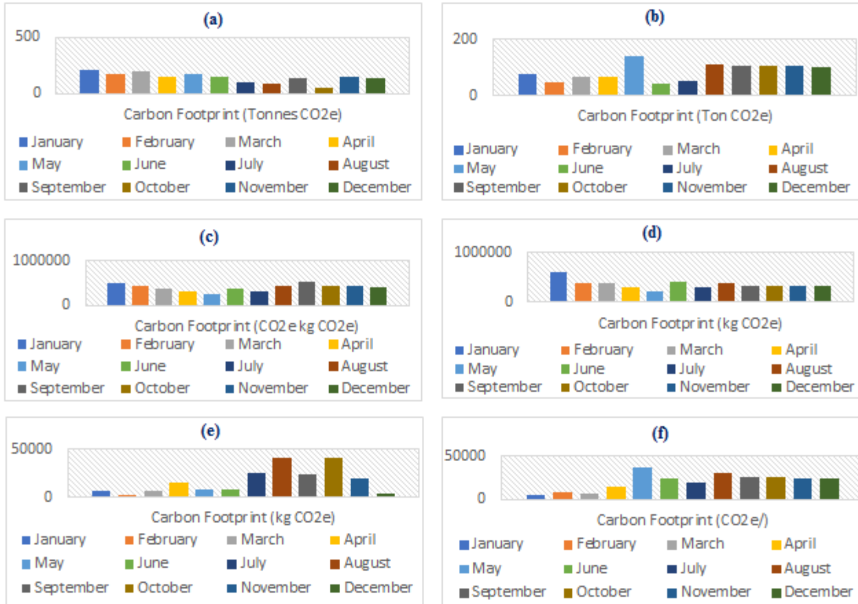


Fig. 5: Carbon emission from Study Area S_2 from -a) electricity consumption (2022), b) electricity consumption (2023), c) gas consumption (2022), d) gas consumption (2023), e) diesel consumption (2022), f) diesel consumption (2023).

Carbon emission i.e. carbon footprint from different activities in S_2 shows that gas combustion is the main emission source. In 2023, almost all emission (4343209 kg CO_2e) came from gas combustion.

3) Study Area S_3: This area contributes to carbon emission only by electricity and diesel consumption where electricity contributes more.

Table 2: Electricity and Diesel Consumption Data of Study Area S_3 (2022-23).

Emission sources	Year	Consumption	Emission factor	Carbon Footprint (kg CO_2e)
Electricity	2022	803.13 MWh	670 kg CO_2e/MWh	538097.1
	2023	1089.258 MWh	670 kg CO_2e/MWh	729802.86
Diesel	2022	33950 Liter	2.68 total CO_2e kg CO_2e/unit	90986
	2023	36200 Liter	2.68 total CO_2e kg CO_2e/unit	97016

It is seen that more than three-fourths part of total emission comes from electricity which is above 5 lakhs kgCO_2e and only ninety thousand (almost) kgCO_2e comes from diesel.

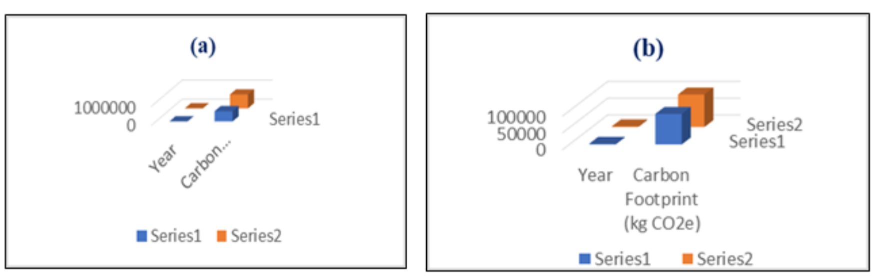


Fig. 6: Carbon emission from S_3 (2022-23) from -a) electricity consumption, b) diesel consumption.

From the above figure it is seen that carbon footprint values in 2023 from both sources (electricity and diesel are higher than in 2022 which indicates a moving towards higher emission.

4) Study Area S_4

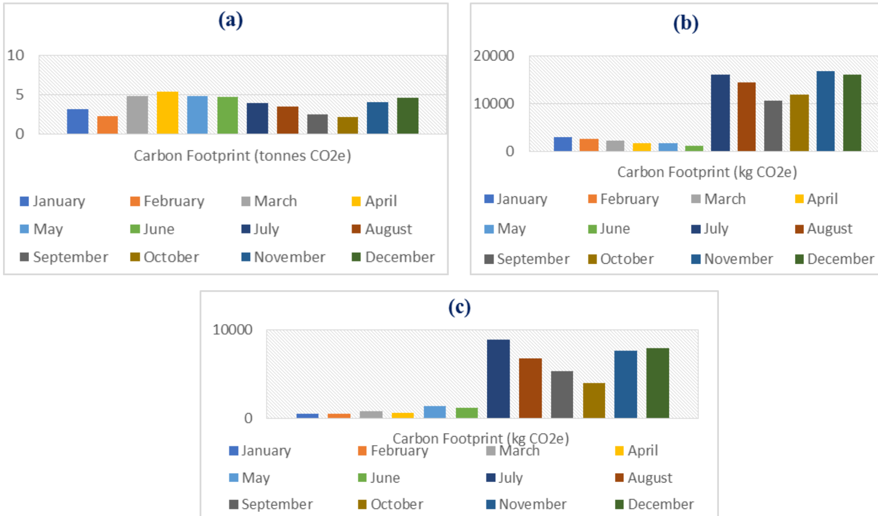


Fig. 7: Carbon emission from Study Area S_4 (2023) from-a) electricity consumption, b) gas consumption, c) diesel consumption.

This figure shows that emissions from electricity and diesel consumption reached their highest values in the middle of the year but emissions from gas consumption reached to its peak value at the end of the year (November).

Table 3: Total carbon emission from Study Area S_4 (2023).

Emission Source	Carbon footprint (kg CO_2e)
Electricity	46414.25
Gas	80817.99448
Diesel	45667.2
Total:	**172899.44448**

In this case, Gas combustion is responsible for almost half of the total carbon footprint which is slightly lower than that of other study areas. Diesel combustion contributes nearly one fourth of the total emission and the remaining comes from electricity consumption.

5) Study Area S_5

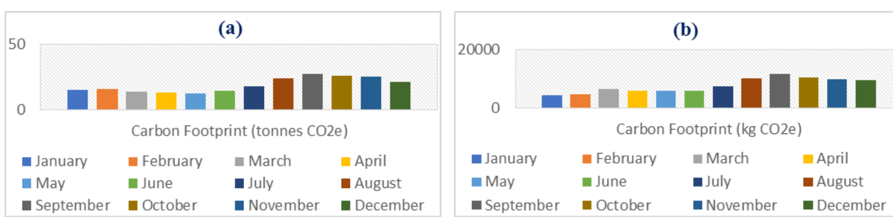


Fig. 8: Carbon emission from Study Area S_5 (2022) from-a) electricity consumption, b) diesel consumption.

Carbon emission i.e. carbon footprint from different activities in S_5 can be graphically represented as below:

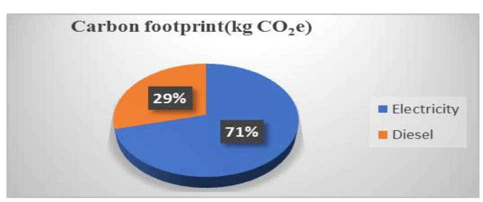


Fig. 9: Total Carbon emission from S_5.

The chart above shows that 71% emission is coming from electricity and the remaining from diesel combustion, as no gas is combusted in this area.

Analyzing all the data collected from different textile industries, it is seen that in all industries major emission comes from gas combustion and the minor contributor to emission is diesel combustion. In areas where gas combustion is not required, electricity contributes to a greater part of emission and carbon footprint. The results show that the highest carbon footprint accounted from Knittex Industries Limited (Study area S_2). Here, industries consuming more fuel contribute more to greenhouse Gas emission or more carbon footprint resulting in rapid warming of earth and climate change. On the other hand, industries smaller in size and do not contain all sections of garments manufacturing emit lower carbon into the atmosphere. Carbon emission from gas, diesel and electricity consumption in Gazipur industrial areas is significantly contributing to some major adverse impacts including human health and environmental impact. As carbon is emitted at this rate, this will be a cause for global warming and climate change which is not good for us.

Impacts of Carbon Emission: Increasing rate of emissions from industrial areas can cause numerous negative impacts including the followings:

Impacts on the Environment: A higher amount of carbon dioxide in the atmosphere is causing extraordinary climate change, such as wildfires, extended rains, tropical storms, and temperature increases.
Impacts on Human Health: The natural growth of food crops is impacted by climate change, droughts, and floods. This can lead to low crop productivity, a rise in malnutrition, and health problems.
Impacts on Wildlife: The erratic weather patterns brought on by rising pollution levels and global warming are endangering the existence of many wildlife species and putting them in danger of going extinct.
Impacts on Economic Growth: Numerous investigations have demonstrated the impact of pollution and climate change on a nation's natural resources and agricultural output.

Carbon Reduction Techniques: There are some carbon reduction or carbon dioxide emission reduction techniques that can be applied in textile industries are

Gas Trapping System: By using the G-trap technique, industries can save a significant amount of heat and steam, which in turn lowers carbon emissions [9].
Boiler with Economizer System: An economizer heats the boiler feed water in addition to lowering the temperature of the stack. By utilizing an economizer with a boiler to save fuel for heating water, CO_2 emissions can be reduced [10].
Auto blowdown System: By minimizing excess blowdown, automatic blowdown control systems conserve energy and lower carbon emissions from industrial boilers [11].
Upcycling of Waste Cotton: Non-textile products such as polypropylene bags and beer bottles can now be broken into a fine particulate which is then melted and extruded into usable fibers. Processes like these create less waste and reduce the distance required for sourcing of some textile components [12].
Steam Condensate Recovery and Reuse: Less makeup water is needed when more condensate is returned, which reduces the need for fuel, chemicals, and treatment expenses [13].

Some carbon reduction strategies:
- Polluting Less in Textile Dyes
- Using Fewer Resources
- Using Alternative Fabrics
- Resource Conservation Techniques:
  - Turning off light and electronics when not in use
  - Use of LED Lights
  - Boiler and Steam Line Insulation

Conclusion: Main emission sources as well as major contributors to carbon footprint in textile industries are gas and diesel combustion in boilers and generators. As electricity is required for cutting, sewing and lighting purposes, it is also another source of CO_2 emission. Based on the study result it has been found that the greatest emission comes from gas combustion which is more than half of the total emission in almost all areas. Besides, diesel combustion emits lowest carbon thereby contributing less to carbon footprint impacts. Highest value of GHGs emission is recorded in study area S_2 that is 4343209 kg CO_2e. Such emissions can be a significant threat to our climate and surrounding environment of Gazipur district. Increased carbon footprint can also affect human health, wildlife and the economy of the area. The better way to reduce carbon footprint is to adopt alternative technologies in industrial manufacturing processes. Industries should adopt carbon reduction strategies (i.e., using gas trap, materials upcycling, condensate recovery, effluent gas boiler, energy conservation measures) and utilize the opportunities of carbon trading. As a result, textile industries in Gazipur industrial area can contribute significantly to reduce global warming and climate change and their adverse impacts.

Recommendations for Future Work
- In this study, carbon footprint from transport, equipment operation duration, floor area of building and raw materials consumption are not considered.
- So, it is recommended for any future work to consider carbon emission from these source activities in industries if proper data is available.

- It's also recommended that industries should use renewable (i.e., wind, solar, biomass) and alternative sources of energy as long as possible, install emission friendly technologies and maintain all carbon reduction techniques and strategies in future.

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