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Greenhouse Gas Emission Due to Iron Recycling in the Chittagong City Corporation, Bangladesh

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Abstract

Global warming due to greenhouse gas (GHG) emission is the most challenging issue nowadays. Life Cycle Assessment on different materials contributes to this by articulating greenhouse gas (GHG) emission in various stages. This study quantifies GHG emissions from the iron recycling process of Chittagong City Corporation (CCC). It collects technical data through an on-site visit and questionnaire survey to each of the selected processing industries and waste depots by a semi-structured questionnaire. The study shows that total GHG emission is 314 kgCO_2-eq/ton of scraps in waste depots. Processing industries contribute GHG of 605.3 kgCO_2-eq/ton for billet production and 80.3 kgCO_2-eq/ton for rod production from electricity consumption. Moreover, these industries produce GHG of 0.875 kgCO_2-eq/ton for billet production and 2766.11 kg CO_2-eq/ton for rod production from natural gas consumption. The study contributes to global warming reduction practices from iron waste recycling in Bangladesh.

Keywords: *Electricity consumption; Greenhouse gas emission; Iron recycling; Natural gas consumption*

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গ্রীণহাউজ গ্যাস নির্গমণের কারণে বৈশ্বিক উষ্ণায়ণ বর্তমানে সবচেয়ে বড় উদ্বেগের বিষয়। লাইফ সাইকেল এসেসমেন্ট বিভিন্ন পদার্থের উৎপাদন প্রক্রিয়ায় কি পরিমান গ্রীণহাউজ গ্যাস নির্গমণ হয়, তা স্পষ্ট করে দেয়। এই গবেষণা চট্টগ্রাম সিটি করপোরেশনে লোহা পূনরাবৃত্তি কাজের বিভিন্ন পর্যায়ে গ্রীণহাউজ গ্যাস নির্গমণ পরিমাপ করে। এটি অর্ধ-কাঠামো ভিত্তিক প্রশ্নমালার মাধ্যমে নির্ধারিত লৌহ পূনরাবৃত্তি মূলক কারখানা ও লৌহ-বর্জ্য ভাগাড় থেকে কারিগরি তথ্য সংগ্রহ করে। গবেষণায় দেখা যায়, লৌহ-বর্জ্য ভাগাড়ে প্রতি টন বর্জ্যের জন্য ৩১৪ কেজি কার্বন-ডাই অক্সাইড সমমানের গ্রীণহাউজ গ্যাস নির্গমণ হয়। বিদ্যুৎ ব্যবহারের মাধ্যমে লৌহ পূনরাবৃত্তি মূলক কারখানা প্রতি টন বিলেট উৎপাদনের জন্য ৬০৫.৩ কেজি এবং প্রতি টন রড উৎপাদনের জন্য ৮০.৩ কেজি কার্বন-ডাই অক্সাইড সমমানের গ্রীণহাউজ গ্যাস নির্গমণ করে। অধিকন্তু, এই কারখানাগুলো প্রাকৃতিক গ্যাস ব্যবহারের মাধ্যমে প্রতি টন বিলেট উৎপাদনের জন্য ০.৮৭৫ কেজি এবং প্রতি টন রড উৎপাদনের জন্য ২৭৬৬.১১ কেজি কার্বন-ডাই অক্সাইড সমমানের গ্রীণহাউজ গ্যাস নির্গমণ করে। এই গবেষণা বাংলাদেশে লৌহ-বর্জ্য পূনরাবৃত্তি করার ক্ষেত্রে বৈশ্বিক উষ্ণায়ণ হ্রাস করার কাজে অবদান রাখবে।

1. Introduction

Evaluation of a solid waste management system needs a lifecycle-based calculation of greenhouse gas emission. Municipal solid waste management is a critical issue due to its increasing annual generation rate (2-3%) for developing countries [1]. It is a global concern subject as a high contributor to global greenhouse gas (GHG) emissions [2]. Solid waste management activities, such as- waste transportation, composting, open burning, incineration, mix waste landfilling, mechanical and chemical treatment, emit GHGs [3]. Life Cycle Assessment (LCA) based study on GHG emission has already been conducted in different countries, like- China, Thailand, and Canada. Based on LCA, estimated GHG emission from Municipal Solid Waste Management (MSWM) was 467.34 Mg CO_2 per year in Tianjin, China [4]; 1006 kg CO_2–eq from 1 ton of Municipal Solid Waste (MSW) in Phuket, Thailand [5]; 25 tons of CO_2–eq at 2001 in Canada [6]. In Bangladesh, the informal sector recycles about 4 to 15% of the total solid waste generated [7]. The industrialized countries have a different scenario having a formal sector dealing with this. The law and general public concerns regulate this resource recovery. The contribution of the waste sector is 13% of total GHG emissions in Israel [8].

Approximately 30 to 40% of the total anthropogenic methane emits from waste management in Finland [9].

LCA of iron can provide an overview of the environmental aspects of different strategies of the iron waste management system and can compare the environmental impact of these strategies [10]. It helps understand and correlate between iron waste management and GHG emission. This management can give a database of GHG emissions at different industrial levels [11]. However, day by day, the iron scraps are being increased with a variable gradient from place to place. These increased amounts of iron wastes are generated from rapid urbanization and mismanagement of waste systems [12].

Recycling is becoming an essential element of solid waste management programs in many countries. Recycling aims to cycle back waste products from the waste stream into raw materials for new or valuable products [12]. Recycling, therefore, can cost less than disposal. In cases where there is strong public support for recycling, citizens pay for recycling services as a regular part of their solid waste collection and disposal fees. There are a variety of options for developing a recycling system that meets the needs of the community.

While reviewing the literature, several studies discussed solid waste generation and management facilities [7], and solid waste recycling [13]. However, no study reveals the quantification of GHG emissions from the recycling of iron wastes in Bangladesh. The objectives of the study were to quantify the GHG emissions from the existing iron recycling process in the CCC, and to identify which stage was more responsible for GHG emissions.

2. Materials and Methods

2.1 Description of the study area

The geographic scope of this study is the CCC area from March 2016 to July 2016. Chittagong, a port city, lies in the southern region of Bangladesh. It is also known as the commercial capital and the second-largest city in Bangladesh. It is one of the fastest-growing cities and a major industrial zone in Bangladesh. It lies in the southeastern part of Bangladesh between 22°14′ and 22°30′ North latitudes and between 91°45′ and 91°53′ East longitudes on the banks of the Karnaphuli river [14]. Chittagong city covers a total area of 157 km^2. The population census of 2011 finds that the total population of Chittagong city is 25,92,439 with a population density of 16,513 per km^2 in total 5,58,097 households. The CCC consists of 41 wards, including the North and South zone. Among 41 wards, 24 are conservancy, and 17 are non-conservancy wards. Because of Chittagong port's presence, a large number of economic and industrial activities are held in the CCC. There are some industrial belts of many medium and heavy industries located at Fouzdarhat, Kalurghat, Baizid Bostami, and Potenga industrial areas.

Since this city has a large population and carries out dense commercial activities, the generation of solid waste is also increasing rapidly. The total average waste generation is 1300-1356 tons/day. Per capita waste generation is 0.48 kg/day in the CCC [15]. The study selected the CCC purposively as huge recycling of irons happens over there.

2.2 Existing municipal solid waste management system of Chittagong City Corporation

The CCC is the urban local government, the only formal organization for Municipal Solid Waste Management (MSWM). The conservancy department of the CCC conducts the MSWM activities of the CCC. The existing MSWM system is consisting of four methods. These are MSW collection, composting, recycling of inorganic waste, and landfilling. The informal private sector completely recycles organic waste. Waste pickers, locally called "*Tokai*", are engaged in the collection of recyclable waste materials from household building and waste dumping places. The locally available shop known as "*Vangari*" or "*Scrap dokan*" buys these recyclable wastes.

2.3 Methods

2.3.1 Life cycle assessment (LCA)

LCA, an evaluation tool, calculated the environmental impacts of iron waste recycling under this study. Among the environmental impacts, the study only considered GHG emission. LCA comprises four significant stages: goal and scope definition, life cycle inventory, life cycle impact analysis, and interpretation of the results.

The study evaluates the GHG emissions from the iron waste recycling process in the CCC area from a life cycle perspective. Environmental impacts considered energy consumption in the form of fuel and electricity. Components of the recycling process were the collection, storing, transportation, and processing.

The functional unit selected for quantification of GHG emission is kg CO_2-eq/ ton of iron scraps. The system boundary in this study starts with the collection of iron wastes. The boundary ends at the steel re-rolling mills processing billets and rods from the iron waste. Within the system boundary, the study considers only energy inputs such as fuels and electricity. Figure 1 shows the system boundary of the LCA study.

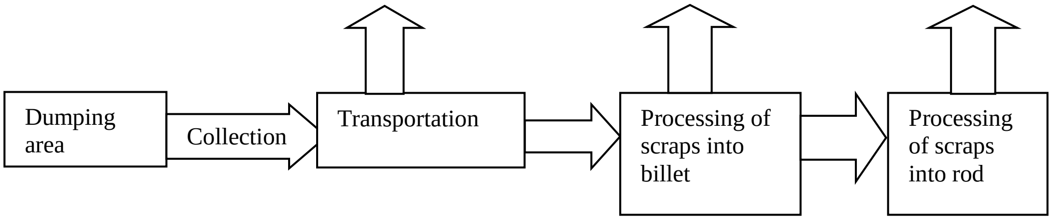

Figure 1. The system boundary of the study area in the recycling of iron in the Chittagong City Corporation.

2.3.2 Life cycle inventory

The life cycle inventory (LCI) aims at identifying and quantifying the environmental interventions related to the system and results in a list of environmental inputs and outputs. Collection of data, their validation, and calculation methods are involved in the LCI. The small depots and the processing industries delivered detailed data about the recycling of iron wastes (amount of iron waste, fuel consumption for their transportation, natural gas, and electricity consumption for their processing). The study used the emission factors for fuels and electricity consumption to calculate the GHGs.

2.3.3 Impact assessment

The LCI assessment determines environmental impacts from the inventory. It also determines the overall environmental performance of the product. Data obtained from the LCI evaluates environmental impacts based on the data obtained. This study considers only the GHG emission in environmental impacts.

2.3.4 Data collection and analysis

The study collected primary data from 25 small depots and 7 iron waste processing industries (Table 1). A reconnaissance survey assessed the feasibility of the study. The study collected data from *Vangari* (waste depots) and steel re-rolling mills (processing industries) by a semi-structured questionnaire. The small depots delivered the data on collection sources, the amount of scraps gathered, and electricity consumption. In addition to this, the processing industries delivered the data on the source of collection, collection process, the input of iron scraps per ton of billet production, fuel consumption for transportation of scraps, consumption of electricity, and natural gas for billet and rod production.

Table 1. List of the processing industries in the Chittagong City Corporation.

Name of the industry	Latitude	Longitude
Baizid Steel Mills	22.374440	91.814343
BSRM(Bangladesh Steel Re-rolling Mills Ltd.)	22.392550	91.816183
CSRM (Champa Steel Rolling Mills)	22.544436	91.694589
Islam Steel Mills Ltd.	22.370000	91.816896
KDS Steel Accessories	22.382845	91.808412
RSRM (Ratanpur Steel Re-Rolling Mills Ltd.	22.388050	91.812183
Saleh Steel Mills	22.374357	91.812397

2.3.4.1 Greenhouse gas emission from the transportation of iron waste

Transportation of iron wastes for recycling consumes fossil fuel. Fossil fuel combustion emits GHG into the atmosphere. In Chittagong, vehicles used for transportation of iron wastes use diesel. Combustion of diesel releases CH_4, N_2O, and CO_2 [16, 17]. This study considers only CO_2 as this is the main component of greenhouse gases emission from transportation. The following equation calculates GHG emission from transportation:

$$\text{Emissions}_T = \frac{\textit{Fuel (units)}}{\textit{Wastes (tons)}} \times \text{Energy (MJ/unit)} \times \text{EF (kg } CO_2\text{/MJ)}$$

Here,

Emissions $_T$ = Emissions from transportation (kg CO_2/ ton of waste transported)
Fuel (units) = Total amount of diesel consumption per month, (Diesel in Liters)
Waste (tons) = Total amount of transported per month
Energy (MJ/unit) = Energy content of the fossil fuel (e.g. diesel: 36.42 MJ/L)
EF = CO_2 emission factor of the fuel (e.g. diesel: 0.074kg CO_2/MJ)

2.3.4.2 Greenhouse gas emission from electricity consumption

Both the small depots and iron waste processing industries consume electricity to store and process scraps into billets and rods. In Bangladesh, the powerhouse mainly produces electricity with natural gas, coal, heavy furnace oil, high-speed diesel, and hydropower. Table 2 shows a list of sources of electricity generation in Bangladesh.

Table 2. Sources of a generation of electricity with their percentage in the national grid.

Fuel type	Capacity (MW)	Percentage (%)
Natural gas	7628.00	61.82
Coal	250.00	2.03
Heavy furnace oil	2675.00	21.68
High-speed diesel	956.00	7.75
Hydroelectricity	230.00	1.86
Imported from India	600.00	4.86
Total	12339.00	100

Source: [18]

The study used emission factors to calculate GHG emission from the consumption of electricity. Table 3 shows emission factors for the quantification of GHG emission.

Table 3. Emission factors for quantification of GHG emission.

Fuel type	Emission factors	Unit	Source
Natural gas	0.185	kg CO_2-eq/Kwh	[19]
Coal	3.26	kg CO_2-eq/Kwh	[19]
Heavy furnace oil	2.96	kg CO_2-eq/Kwh	[20]
High speed diesel	0.733	kg CO_2-eq/Kwh	[21]
Hydroelectricity	0.236	kg CO_2-eq/kWh	[21]
Imported from India	0.185	kg CO_2-eq/kWh	[20]

By using the following equation, the GHG emission was calculated using Table 2 and Table 3.

Emissions = [Percentage of electricity from coal (2.03%) × total electricity (kWh) × 3.26 Kg CO_2-eq/kWh] + [Percentage of electricity from natural gas (61.82%) × total electricity (K\kWh) × 0.185 Kg CO_2-eq/kWh] + [Percentage of electricity from heavy Furness oil (21.68%) × total electricity (kWh) × 2.96Kg CO_2-eq/kWh] +

[Percentage of electricity from high speed diesel (7.75%) × total electricity (kWh) × 0.733Kg CO_2-eq/kWh] + [Percentage of electricity from hydropower (1.86%) × total electricity (kWh) × 0.0236 Kg CO_2-eq/kWh] + [Percentage of electricity imported from India (4.86%) × total electricity (kWh) × 0.185 Kg CO_2-eq/kWh]. Thus the total GHG emission from 100 kWh electricity production was calculated 88.85 kg CO_2-eq.

3. Results and Discussion

3.1 Supply chain of iron waste for recycling

The study found that iron wastes generally originated from residents and commercial purposes. Those wastes were kitchen wastes, electrical products, construction products, and other household products. Firstly, these scraps went through small depots, locally known as *Vangari* and then to processing industries. Then those finally entered into the recycling process. Figure 2 shows the supply chain of iron wastes.

Tokai collected iron wastes from dumping sites and households and then sold them to the small depots. The processing industries, then, bought the scraps from the depots, crushed the scraps, and converted them into billets. From billets, the industries produced rods as the end product.

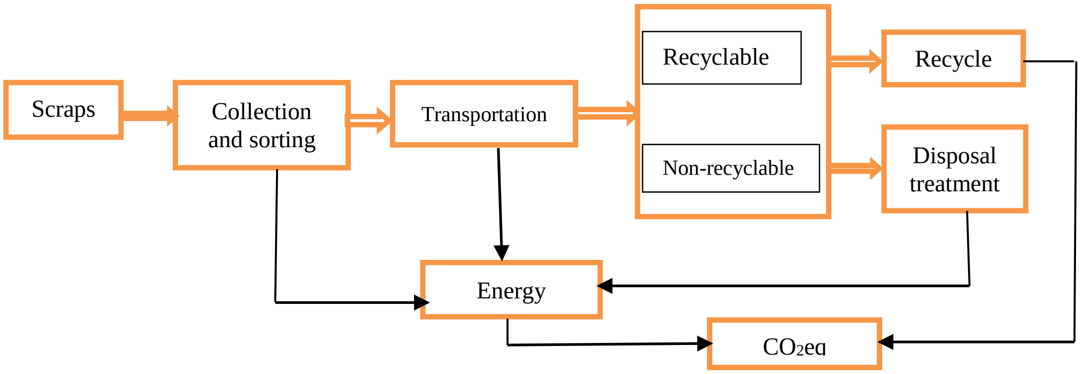

Figure 2. The supply chain of iron wastes of the recycling system in the Chittagong City Corporation.

Each small depots reported collecting 876±45 tons of iron wastes per month. Among them, 44.92% of their total scraps were from the dumping sites, 36.16% from households directly, and 18.92% from the *Tokai*. The steel processing industries collected a significant quantity of the scraps from the small depots. That was 20060±802 tons of iron scraps per month from the small depots having 68.60% (Figure 3). They collected the rest of the scraps from different shipbreaking industries and other commercial sites. Different areas of the Chittagong city contributed differently for supplying scraps to the recycling industries, i.e., Fauzdarhat area, 16.28%; Patenga area, 8.14%; and Sitakunda area, 6.98%.

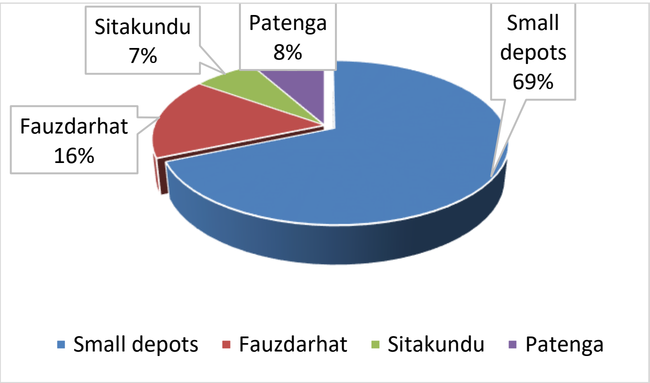

Figure 3. Scraps collection by the steel processing industries in the Chittagong City Corporation.

3.2 Greenhouse gas emission

3.2.1 Sources of GHG emission in the recycling process

The system boundary identified three stages emitting GHG. These were waste storage, waste transportation, and waste processing. In the small depots, scraps were initially stored for selling to the steel re-rolling industries. The small depots did not process anything there. They used electricity for storing the scraps until they sold these to the processing industries. In small depots, the average energy consumption in electricity is 353±14.99 kWh/ton of wastes.

In the processing industries, scraps were first processed into billets and then rods by industrial burner, oven, and different machines. Oven runs by natural gas and other machinery by electricity. So converting iron scraps into billet and rod is another primary source of GHG emission in the iron recycling process in Chittagong city. Average electricity consumption in this stage for processing iron into billet was 681.25±12.27 kWh/ton, and electricity consumption for the billet processing into rod was 90.38±9.60 kWh/ton. Along with this, the use of natural gas for billet production was 0.85±0.44 m^3/ton, and for rod, production was 45.63±2.58 m^3/ton.

3.2.2 Greenhouse gas emission from electricity consumption

Based on electricity consumption in the small depots, the quantity of emitted GHG from this electricity consumption was 314±13.32 kg CO_2-eq/ton (Figure 4).

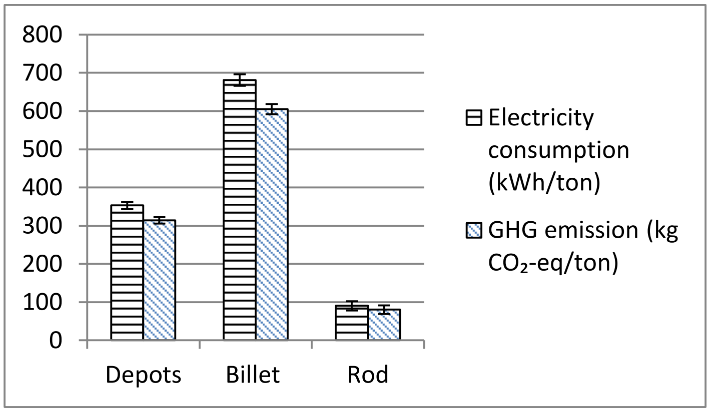

Figure 4. Greenhouse gas emission from electricity consumption in small depots and the recycling industries in Chittagong City Corporation.

In the processing industries, billet production contributed 605.3±10.91 kg CO_2-eq/ton, and rod production added 80.3±8.53 kg CO_2-eq/ton.

3.2.3 Greenhouse gas emission from the transportation of scraps

Transportation of iron scraps from the depots to the processing industries needed 0.01±0.001 liter diesel per 1 ton. Direct GHG emission from waste transportation was about 0.04±0.004 kgCO_2-eq/ton of transported scraps (Figure 5).

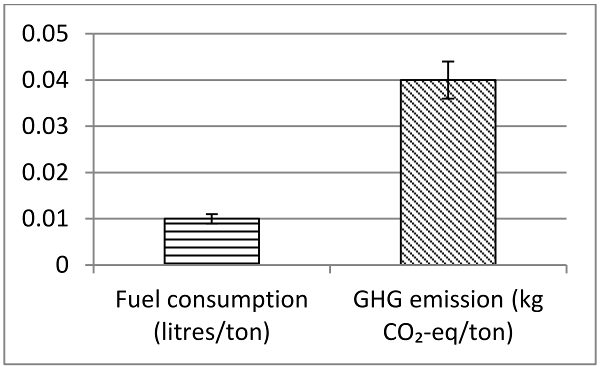

Figure 5. GHG emission from the transportation of scraps in processing industries in the Chittagong City Corporation.

3.2.4 Greenhouse gas emission from natural gas consumption in processing industries

The GHG emission from natural gas use for billet and rod production was 53.05±26.72 kg CO_2-eq/ton and 2766.11±156.23 kgCO_2-eq/ton, respectively. Figure 6 shows the average consumption of natural gas and GHG emission in processing industries for billet and rod production.

In the recycling of iron, this study identifies the processes from which GHG emissions occur. The results from the LCA of iron recycling in the CCC show that the emission of GHG is high in the processing industries in comparison to the small depots. Energy consumption by natural gas is one of the causes for this higher emission in processing industries, as in small depots, there is no such type of energy consumption. Another purpose for this output is more consumption of electricity in processing industries as for maintenance system and also burner system for processing of rod. The processing industries use the machine for crushing the scraps, and it takes a more extended time. On the contrary, in small depots, no machine runs for the operation.

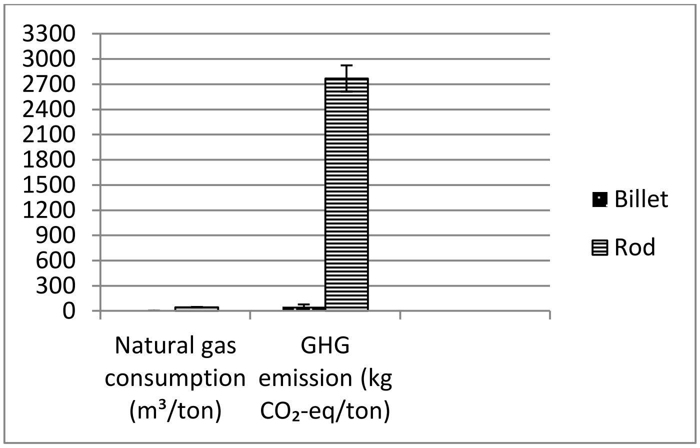

Figure 6. Greenhouse gas emission from natural gas consumption for billet and rod production in processing industries in the Chittagong City Corporation.

Iron waste management includes generation, collection, transportation, system processing, recycling, disposing, and monitoring iron waste. The waste management system considers safe treatment and system management of greenhouse gas generation [11, 22]. Iron waste management practice varies from urban to rural areas, from residential to industrial sectors. Locations, characteristics, the quantity, the composition of materials, technology for collection and transportation, labor expenses influence the cost and management of iron wastes.

Recycling expedites the use of waste itself as a resource. It supports waste minimization efficiently. Its objective is to derive the maximum practical benefits from products and to generate the minimum quantity of wastes. It minimizes GHG emissions by lowering energy consumption. It defines material efficiency as a reduction in primary materials. More efficient design, material substitution, product recycling, and material recycling can increase material efficiency. It contributes to energy savings indirectly, reduces GHG emission, and avoids further GHG generation. It works clearly for the products resulting from the energy-intensive production process, such as metals, steel, and plastics [23]. Collecting, sorting, transporting, recycling waste materials provide income to hundreds of thousands of people. Recently, it acknowledged the importance of recycling activities in reducing waste volume, recovering resources, and its economic benefit. Presently, 3R (Reducing, Reusing, Recycling) activities are getting momentum by many Non-Government Organizations (NGOs) and Community Based organizations (CBOs). However, prioritizing of 3Rs among these may not result in a drastic change within a short period but will reap a significant reward in the long run.

4. Conclusion

This study shows the current GHG emission status of the iron recycling system in the Chittagong City Corporation of Bangladesh. It falls in the critical metals category, which is valuable as a recyclable material. From the overall assessment of the result, it concludes that processing industries are more responsible for GHG emissions than waste depots. In the processing industries, billet production contributed a significant quantity of GHG than that of rod production due to electricity use. Billet production contributed 605.3±10.91 kg CO_2-eq/ton, and rod production added 80.3±8.53 kg CO_2-eq/ton. On the contrary, rod production contributed the highest GHG emission than billet production due to natural gas use. For billet and rod production, GHG emissions were 53.05±26.72 kg CO_2-eq/ton and 2766.11±156.23 kgCO_2-eq/ton, respectively. However, this study will help to extract the suitable process of recycling from this study and will be helpful in strategy development on global warming mitigation in Bangladesh.

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