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MISCELLANEOUS

IDENTIFYING THE METHODS FOR GREENHOUSE GAS EMISSION INVENTORY AND APPLICATION FOR THE METALLURGY INDUSTRY

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Abstract: *Metallurgical processes require vast energy from primary (coal, oil, gas) and secondary (electricity) sources. Therefore, this is one of the main sources of greenhouse gas (GHG) emissions in total national GHG emissions. The article has selected two typical steel factories to represent two popular steel production technologies in Vietnam, namely Electric Arc Furnace (EAF) and Basic Oxygen Furnace (BOF). The study applies methods of environmental observation and analysis, sampling, sample preservation, on-site measurements, and laboratory analysis methods. The results show that, for EAF steel production technology, the CO_2 emission of EAF technology is from 3800 - 7160 mg/Nm^3, the CH_4 emission is from 1.86-3.05 mg/Nm^3, and the N_2O emission is from 0.69 - 1.02 mg/Nm^3. The calculation of the GHG emission factor for the steel production sector will be compensation for future GHG inventory and calculation.*

Keywords: *Emission factor; GHG inventory, metallurgy industry*

1. INTRODUCTION

The metallurgical process requires enormous energy from primary (coal, oil, gas) and secondary (electricity) sources. Also, coke is an input fuel source for the product. In general, the burning of fossil fuels, the usage of electricity, and coke are the main drivers of emissions in the metallurgical process. However, metallurgical technologies such as fire, hydration, and electrolysis will cause different emissions. Therefore, it is necessary to identify metallurgical processes and inputs of materials and fuel to develop a scientific basis for calculating and forecasting emissions. It is also essential to determine the exhaust gas and the exhaust gas composition at each stage in the metallurgical process. Based on this information, the research team has been developed calculation methods suitable for the characteristics of raw materials, fuels, and technologies in Vietnam.

The GHG emission assessment process is based on the content of resource inventory. Resources are focused on assessing emissions of production facilities with different levels of technology investment and thereby building the main range of greenhouse gas emission factors for this industry.

The emission source inventory (or pollution source inventory) is the process of developing a complete list of sources of environmental pollution and discharging their estimated amount in a specific geographic area over a specified period. Inventory types may include emissions inventory; inventory of water pollution sources, inventory of solid waste disposal, hazardous waste discharge inventory, inventory of a particular substance, etc.

The emission source inventory helps identify the sources of pollutants, the types of activities causing the emissions, and the extent of the processes that discharge pollutants into the environment, thereby assessing the scale and scope of the emissions.

This method is a crucial tool in environmental assessment, management, and production efficiency improvement. Through calculation tools to capture the actual emissions situation, it forecasts the amount of GHG emissions, implements emission source controlling measures. The development of policies for emission sources management is the basis for developing other related general systems. Appropriate guidelines are proposed on reliable data from emission source inventory.

Typically, each emission source inventory program will have two main compulsory processes, including:

1.1. Reviewing the facilities having GHG emission activities

This process conducts a review to fully list the production facilities that emit GHG into the environment and to determine the characteristics of the production processes related to the GHG emission. Information of interest in this process includes:

- List the production facilities, types of industrial production in the region

- For each facility, some requirements are needed:

• Identify emission sources of the production facility: exhaust through chimneys, sewers, or scattered emission from equipment, storage, etc.

• Determine the emission of the production establishment, such as exhaust gas, wastewater, solid waste, etc.

• Survey the facility's production technology, capacity, etc.

• Determine the demand for raw materials, fuel, and water, etc.

• Determine the characteristics of the existing wastewater, exhaust treatment systems, and environmental protection solutions

1.2. Estimating the amount of GHG emission into the environment

Based on the list of emission sources from the step of reviewing the production facilities, the authors analyze selected methods for emission source inventory to find the appropriate emission estimation method. The necessary data information for the calculation is collected accordingly.

2. OVERVIEW OF THE RESEARCH OBJECT

2.1. Thai Nguyen Iron and Steel Joint Stock Company - Luu Xa steel refinery factory

Raw materials for the production of steel billets are rich iron ore and iron ore concentrate. Fuel used is coke coal and anthracite. Also, there are other coolants, additives, and fluxes, such as iron scrap, limestone, dolomite, and iron alloys, etc.

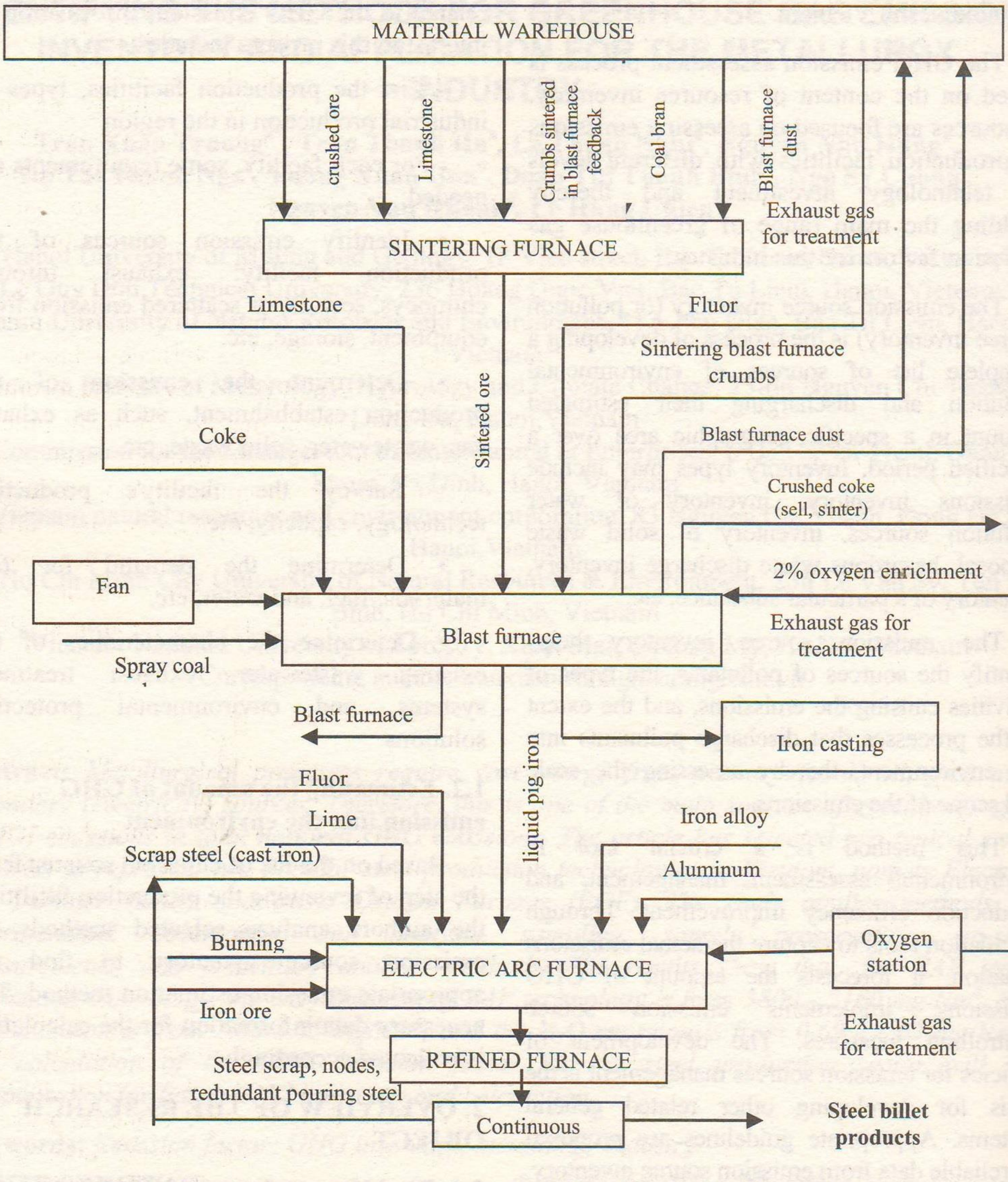

Fig 1. Production technology diagram at Luu Xa steel refinery factory

The production process includes the main stages of sintering iron ore, blast furnace iron, blast steel in a refining furnace, and casting steel billets continuously.

Sintering iron ore concentrates to bond iron ore and scrap iron ore into a larger particle size suitable for blast furnace iron smelting, and at the same time, reducing impurities in the ore such as sulfur. Sintering equipment includes conveyor belts, including sintering tape, cooling tape, crushing machine, collecting dust and cleaning gas, etc. Ore is mixed with additives to create suitable alkalinity, using blast furnace coal gas as pilot fuel.

Blast furnace iron refining is used for smelting sintered ores and a part of lump ore into liquid iron before it is transferred to steel refining. Fuel used for the blast furnace is mainly coke with high durability and high calorific value burned to create high temperatures and a reconstituted environment for the blast furnace. Besides, there is a coal dust injection system to reduce consumption, loss of cup, reduce production costs.

Liquid iron from the blast furnace, removed from the furnace through a container, is transported to the steel refining stage to perform the steel refining process, blow impurities reduction, steel water refining, and steel grade alloying. Finally, it transforms into billet products, under quality check, and will be sold in the market. Industrial oxygen production station is used to provide 99.5 % O_2 gas for iron smelting, sintering, drying, etc.

2.2. Hoa Phat Steel Joint Stock Company

Steel billet production

Raw materials for the production of steel billets are rich iron ore and iron ore concentrate. Fuel used is coke coal and anthracite. Besides, there are other coolants, additives, and fluxes such as scrap iron, limestone, dolomite, and iron alloys, etc.

The production process includes the main stages of sintering iron ore, blast furnace iron, blast steel in a refining furnace, and casting steel billets continuously.

Sintering iron ore concentrates for bonding iron ore and scraps iron ore into a larger particle size suitable for blast furnace iron smelting. At the same time, impurities are reduced in ore (sulfur is an example). Sintering equipment includes conveyor belts, sintering tape, cooling tape, crushing machine, collecting dust and cleaning gas, etc. Ore is mixed with additives to create suitable alkalinity, using blast furnace coal gas as pilot fuel during sintering.

Blast furnace iron refining is used for smelting sintered ores and a part of lump ore into liquid iron before it is transferred to steel refining. Fuel used for the blast furnace is mainly coke with high durability and high calorific value, which is burned to create high temperatures and a reconstituted environment for the blast furnace. Also, there is a coal dust injection system to reduce consumption and production costs.

Liquid iron from the blast furnace, removed from the furnace through a container, is transported to the steel refining stage to perform the steel refining process, blow impurities reduction, steel water refining, and steel grade alloying. Finally, it transforms into billet products, under quality check, and will be sold in the market. Industrial oxygen production station is used to provide 99.5 % O_2 gas for iron smelting, sintering, drying, etc.

Steel rolling

Embryos are cut into segments according to technical requirements and then checked. If satisfactory, it will be arranged in batches to prepare the furnace. For unsatisfactory types they will be separately handled and checked for further details before being reported as discarded.

The furnace is designed to feed hot billets through the transfer floor. Embryos taken from the billet yard are loaded into the furnace in sequence by a crane on a loading table through a roller to the door of the furnace, using two 40-ton pushers.

After the billet is heated to the rolling temperature, it is removed by a pusher device to a rolling machine. First, the billet runs on a roller system through the I-rolling system. Here, the billet is divided into two threads to produce different steel products. With the coil steel production stage, after going through the rolling system I, the head and the tail are cut, the remains are continuously going through the rolling machine to make blocks and then form the coils. With rebar product, the billet is going through the rolling machine is continuously cut into segments and cooled on the cooling floor. Finally, the billet is cut to the product size (11.7m) and move to bundle.

With steel production, there must be other stages. The billet, after going through rolling I, continues to run to rolling system II and III then saw into segments. At this time, the rolling object is checked for technical properties combined with cooling before being put into the straightening machine. All finished steel products must undergo a final inspection before being packaged and weighted.

The main equipment in the production line is shown in Table 2. Raw material demand is shown in Table 3. A water source is mainly taken from the Energy facility - Thai Nguyen Iron and Steel Joint Stock Company, with an average of about 160.000 m^3 per month. Domestic water used for the office and dining area is 600 m^3 per month, of which, clean water from the Tich Luong water plant is 300 m^3 per month, and 300 m^3 from well water. The ratio of factory sanitation water to manufacture water is about 0.06 %.

3. METHOD AND DATA

3.1. Measurement of GHG emissions in production stages

Through analysis of the production process diagram and technology of Luu Xa Steel Refining Factory - Branch of Thai Nguyen Iron and Steel Joint Stock Company, the consultant selected the points for GHG emission monitoring as follows:

Table 1. Point and frequency of greenhouse gas monitoring in Luu Xa Steel Refining Factory

No.	Point	Monitoring index	Frequency
1	Sintering furnace	- Gas emissions; - Air quality in the factory area.	Three times
2	Blast furnace	- Gas emissions; - Air quality in the factory area.	Three times
3	Coke production (Coking chamber)	- Gas emissions; - Air quality in the factory area.	Three times
4	Electric arc furnace	- Gas emissions; - Air quality in the factory area.	Three times
5	LF refined furnace	- Gas emissions; - Air quality in the factory area.	Three times
6	Main fuels	Analysis of samples of primary fuels: coal, oil	3 sample x 3 analysis times

Through analyzing the production process diagram and technology of Hoa Phat Steel Factory - Hai Duong, the consultant selected the locations for GHG emission monitoring, as shown in Table 2.

Table 2. Point and frequency of greenhouse gas monitoring in Hoa Phat Steel Joint Stock Company, Hai Duong province

No.	Point	Monitoring index	Frequency
1	Coke production (Coking chamber)	- Gas emissions;	Three times
2	Blast furnace	- Gas emissions;	Three times
3	BOF 3	- Gas emissions;	Three times
4	Sintering furnace 3	- Gas emissions;	Three times

3.2. The applied methods of environmental monitoring and analysis

The main methods of implementing an environmental monitoring program include:

- Methods of field survey, information collection, sampling, rapid measurement of environmental factors;

- Methods of selection, preserving, and analyzing samples on-site and in laboratories according to current Vietnamese standards (TCVN);

- Processing methods, data evaluation, statistics, and comparison with national and international standards.

The technical process of exhaust gas monitoring is applied according to the Circular No. 24/2017/TT-BTNMT on Technical Regulations for environmental monitoring-Section 7 (Chapter II): Monitoring of exhaust gases, specifically:

- Article 28: regulates the location and number of monitoring points following the U.S Environmental Protection Agency (U.S EPA) method 1 or method 1A, details in Appendix 01 attached to the Circular.

- Article 29: Compulsory parameters for direct observation at the field include: temperature, velocity, flow, moisture content, and molar mass of a dry gas molecule, exhaust pressure, details specified in Appendix 02, 03, and 04 attached to the Circular.

- Article 30: Time and quantity of monitoring samples: Samples are taken when the production reaches at least 50 % of the design capacity. The establishment must operate consistently throughout the entire sampling period. The number of samples in each monitoring time is at least 03 samples.

- Article 31: Regulations on methods of observation and analysis in respective current national technical regulations.

The monitoring equipment and methods are selected in detail in the following tables 3 and 4:

Table 3. Methods of taking samples, preserving samples, and measuring in the field

No.	Parameter	Method of application	Monitoring equipment
I	**Gas emission**		
1.	Speed and flow	U.S EPA method 2	
2.	Molar mass of dry gas	U.S EPA method 3	
3.	Moisture	U.S EPA method 4	
4.	Temperature, pressure	Direct measure	

No.	Parameter	Method of application	Monitoring equipment
5.	CO_2	TCVN 8712:2011	Testo 350
6.	N_2O	TCVN 8713:2011	
7.	CH_4	TCVN 8715:2011	
8.	Total dust	U.S EPA Method 5	Gas sampling equipment C5000, ES
9.	CO	TCVN 7242:2003	
10.	NO_x	U.S EPA Method 7	
11.	SO_2	U.S EPA Method 6	
II	Sampling of raw materials and the fuel used		
1.	Coal and coke sampling	TCVN 1693:2008	-
2.	Oil and oil-products sampling	TCVN 6777:2007	-

Table 4. Analytical methods in the laboratory

No.	Parameter	Method of application	Detection limit/ measuring range
I	Gas		
1.	CO_2	TCVN 8712:2011	0,01 mg/Nm^3
2.	CH_4	TCVN 8715:2011	<1.500 mg/Nm^3
3.	N_2O	TCVN 8713:2011	<200 mg/Nm^3
II	Raw materials and the fuel used		
1.	Carbon content	ASTM D3172	

In addition to the exhaust gas samples at the chimney, the consultant proposed to take additional samples of the air from the factory environment, which is directly affected by the gas emission source. The air sampling locations in the workshop areas are selected with the parameters above.

3.3. List of monitoring and laboratory equipment

a. Monitoring equipment

- Dust and flue gas sampling equipment, ambient gas sampling equipment, large-speed total dust sampling equipment, etc.

- Equipment for measuring flue gas flow, measuring device noise, vibration.

b. Analyzing equipment

- GC equipment

UV-VIS, TOC, Fluorescence spectroscopy, etc.

3.4. Description of monitoring locations

The monitoring locations of the topic are described in Table 5 below.

Table 5. List of monitoring location

No.	Monitoring code	Monitoring type	Location	Monitoring location description
		Air environmental composition		
1	KK1	Monitoring emission sources	X:02384756 Y:00434621	In the factory office area
2	KK2		X:02384875 Y:00434500	In the area of electric furnaces, treatment

No.	Monitoring code	Monitoring type	Location	Monitoring location description
				furnaces
3	KK3		X:02384894 Y:00434610	In the area of continuous furnaces and refined furnaces
4	KT1		X:02384875 Y:00434395	At the chimney of a steel furnace

4. RESULTS AND DISCUSSION

4.1. Luu Xa steel refinery factory

Steel furnace No. 1

Table 6. Results of GHG measurement in gas emissions at steel furnace No. 1

No	Parameter	Monitoring method	Unit	Result		
				LT-01.1	LT-01.2	LT-01.3
1.	CH_4	EPA Method 18 + TCCS 27:2015/TTPT	mg/Nm^3	1.28	1.86	3.05
2.	N_2O		mg/Nm^3	0.76	0,69	0.75
3.	CO_2		mg/Nm^3	3,800	6,800	7,160

Sampling location: Gas emissions after treatment - gas treatment system for steel furnace No. 1, furnace LF3 (coordinates: 21°33'30"N; 105°52'07"E)

LT-01.1: First sampling

LT-01.2: Second sampling

LT-01.3: Third sampling

Steel furnace No. 2

Table 7. Results of GHG measurement in gas emissions at steel furnace No. 2

No	Parameter	Monitoring method	Unit	Result		
				LT-02.1	LT-02.2	LT-02.3
1.	CH_4	EPA Method 18 + TCCS 27:2015/TTPT	mg/Nm^3	1.86	2.05	2.40
2.	N_2O		mg/Nm^3	0.85	1.02	0.94
3.	CO_2		mg/Nm^3	5,520	6,800	7,050

Sampling location: Gas emissions after treatment - gas treatment system for steel furnace No. 2, furnaces LF1 & LF2 (coordinates: 21°33'29"N; 105°52'07"E)

LT-02.1: First sampling

LT-02.2: Second sampling

LT-02.3: Third sampling

4.2. Hoa Phat Steel Joint Stock Company

The gas emission test results at the steel furnace No. 1 are presented in Table 8 and at the steel furnace No. 2 shown in Table 9 below.

Table 8. Results of GHG measurement in boiler No. 2

No	Parameter	Monitoring method	Unit	Result		
				KT1.1	KT1.2	KT1.3
1.	CH_4	EPA Method 18 + TCCS 27:2015/TTPT	mg/Nm^3	0.29	0.28	0.28
2.	N_2O		mg/Nm^3	1.40	1.48	1.44
3.	CO_2		g/Nm^3	189.14	185.72	187.52

Sampling location: Boiler chimney No. 2 (post-treatment gas of residual heat-generator gas treatment system - coke furnace)

Table 9. Results of GHG measurement from the sintering furnace No. 2

No	Parameter	Monitoring method	Unit	Result		
				KT2.1	KT2.2	KT2.3
1.	CH_4	EPA Method 18 + TCCS 27:2015/TTPT	mg/Nm^3	30.49	30.89	31.08
2.	N_2O		mg/Nm^3	12.69	12.43	12.62
3.	CO_2		g/Nm^3	54.35	55.96	56.68

Sampling location: Sintering furnace No. 2 (exhaust gas from sintering furnace)

Table 10. Results of GHG measurement from the lime kiln No. 2

No	Parameter	Monitoring method	Unit	Result		
				KT3.1	KT3.2	KT3.3
1.	CH_4	EPA Method 18 + TCCS 27:2015/TTPT	mg/Nm^3	2.02	2.24	2.13
2.	N_2O		mg/Nm^3	0.87	0.88	0.94
3.	CO_2		g/Nm^3	118.69	118.77	120.21

Sampling location: Lime kiln chimney No. 2

Table 11. Results of GHG measurement from blast furnace No. 3

No	Parameter	Monitoring method	Unit	Result		
				KT4.1	KT4.2	KT4.3
1.	CH_4	EPA Method 18 + TCCS 27:2015/TTPT	mg/Nm^3	40.70	38.94	40.44
2.	N_2O		mg/Nm^3	14.31	14.15	14.17
3.	CO_2		g/Nm^3	347.68	344.26	339.76

Sampling Location: blast furnace No. 3's chimney

Table 12. Results of GHG measurement from the BOF No. 3

No	Parameter	Monitoring method	Unit	Result		
				KT5.1	KT5.2	KT5.3
1.	CH_4	EPA Method 18 + TCCS 27:2015/TTPT	mg/Nm^3	2.81	3.01	3.01
2.	N_2O		mg/Nm^3	5.75	5.98	5.85
3.	CO_2		g/Nm^3	351.46	363.88	360.82

Sampling Location: BOF No. 3's chimney

Table 13. Results of GHG measurement from pellet furnace No. 3

No	Parameter	Monitoring method	Unit	Result		
				KT6.1	KT6.2	KT6.3
1.	CH_4	EPA Method 18 + TCCS 27:2015/TTPT	mg/Nm^3	1.42	1.41	1.28
2.	N_2O		mg/Nm^3	2.39	1.72	1.80
3.	CO_2		g/Nm^3	38.69	37.43	39.59

Sampling Location: Pellet furnace No. 3's chimney

Table 14. Result analysis of coal (grease coal)

No	Parameter	Unit	Analyzing method	Result		
				TĐ1.1	TĐ1.2	TĐ1.3
1.	Moisture, W^{tp}	%	TCVN 172:2011	2.71	2.52	2.55
2.	Dry ash, A^k	%	TCVN 173:2011	6.94	7.06	7.05
3.	Heating value, Q^k_c	Kcal/kg	TCVN 200:2011	6,920	7,020	7,040
4.	Volatile content, V^k	%	TCVN 174:2011	21.74	20.88	20.95
5.	Sulfur content, S^k	%	TCVN 175:2015	1.21	1.16	1.14
6.	Carbon content	%	TCVN 255:2007	73.64	72.48	73.50

- *Sampling Location: Coal sample (grease coal) – input for coke production*

5. CONCLUSION

Metallurgy in general and iron and steel production, in particular, is an industry in which, despite the young age of Vietnam, serving the demand for raw materials for the increasingly diverse requirements of life and the national economy and security. However, the production of iron and steel belongs to a heavy industry that contains latent and toxic factors. The technology of producing cast iron, steel billet, rolling steel products has to go through many stages and use large quantities of raw materials such as mineral resources, chemicals. Each stage generates wastes (solid, gas, dust, and wastewater), causing environmental pollution if wastes are not treated. It is also an industry that produces many greenhouse gases, including CO_2, N_2O, and CH_4. However, GHG emissions from metallurgical activities in industrial processes have not been separated from GHG emissions from the energy sector because fossil fuels used for incineration and use cannot be separated input materials. Besides, these reports only use the first-order method with national statistics on product yields and default emission factors according to IPCC Guidelines 1996 revised. This calculation may meet international requirements for reporting GHG emissions but is not detailed enough to support the country in implementing and implementing GHG reduction activities in the metallurgical industry.

This paper aims to measure GHG emissions in the production stages of an iron and steel mill using traditional techniques with a separate coking process, taking and analyzing the carbon content in carbon. Fuel samples simultaneously take and analyze the gas samples burned by the burning (coal, oil, natural gas) used as the burning materials of the plant in the production processes.

The results from the study will be an essential premise for comparison with emission data from iron and steel production plants using advanced technology, from which to study methods to develop national GHG emission factors from the metallurgy industry in general, and iron and steel production in particular.

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