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Greenhouse Gas Emissions Inventory at an Agrochemical Production Facility

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Abstract: Climate change is a pressing global issue primarily driven by increased concentrations of GHGs (Greenhouse Gases) in the atmosphere. GHGs such as CO_2 (Carbon Dioxide), CH_4 (Methane), and N_2O (Nitrous Oxide) trap solar radiation, contributing to global warming. This study presents a GHG emissions inventory for an agrochemical production plant based on ISO (International Organization for Standardization) 14064-1:2018. Emissions from both direct (fuel combustion) and indirect (electricity consumption) sources were quantified. Results indicate that indirect emissions from electricity use account for 91% of total GHGs, while direct emissions from fossil fuel combustion contribute 9%. Electricity consumption emerged as the primary contributor to the plant's carbon footprint.

Key words: Emission factor, greenhouse gas, activity data.

1. Introduction

The greenhouse effect is a natural process by which atmospheric components absorb infrared radiation from sunlight and from the Earth's own emitted radiation [1].

The atmosphere is composed primarily of nitrogen, oxygen, argon, CO_2 (Carbon Dioxide), water vapor, and trace gases. Among these, CO_2 has the greatest impact on climate change, as it is the most abundant GHG (Greenhouse Gas). The increase in CO_2 concentration is directly proportional to the rise in the Earth's average temperature over the past millennium.

At the global level, agreements under the UNFCCC (United Nations Framework Convention on Climate Change) promote economic development aligned with climate resilience and low GHG emissions. The Convention states: "Parties should take measures to conserve and enhance, as appropriate, greenhouse gas sinks or reservoirs" [2]. This commitment has led to the development of scientific, technological, and regulatory tools that impose responsibilities on society and promote changes in resource use, production methods, and economic activities.

As a result of Mexico's commitments under the UNFCCC, the LGCC (General Law on Climate Change) establishes in Article 3 that the industrial sector is required to report its emissions and obtain verification of GHG emissions [3, 4].

ISO (International Organization for Standardization) 14064-1:2018 defines GWP (Global Warming Potential) as "a factor describing the radiative impact of a unit mass of a given greenhouse gas relative to an equivalent unit of carbon dioxide over a specified time horizon." [5].

Based on the GWP, it is possible to measure and compare the emissions of different GHGs and compounds by converting them into CO_2e (Carbon Dioxide Equivalent).

According to Article 6 of the LGCC regulations on the RENE (National Emissions Registry), facilities that emit 25,000 tons of CO_2e or more are required to report their emissions.

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2. Experimental Methodology

A GHG emissions inventory was conducted at an agrochemical production facility located in the state of Hidalgo, Mexico. The plant, which manufactures herbicides, insecticides, rodenticides, fertilizers, and plant nutrients, covers an area of 10,900 m² and employs 180 workers. According to the Ministry of Economy, it is classified as a medium-sized industry.

The facility operates 12 production processes and includes 7 warehouses, a shipping area, a maneuvering yard, 2 laboratories, a processing area, a compressor room, a maintenance workshop, administrative offices, a medical office, a cafeteria, a laundry area, showers and changing rooms, and a hazardous waste storage area.

For inventory purposes, all activities and processes from the arrival of raw materials to the shipment of finished products were considered. The information collected corresponds to a full calendar year. The steps followed to develop the inventory were as follows:

Review of processes and auxiliary services: A site visit was conducted to gather detailed information on all activities carried out at the facility.

Identification of GHG emission sources: Sources of both direct and indirect emissions were identified and documented in accordance with the LGCC and the National Emissions Registry [4].

Selection of the quantification method: The methodology outlined in ISO 14064-1:2018 was used to reduce uncertainty and ensure the accuracy, consistency, and reproducibility of results, based on validated information.

Data collection: Information was gathered on fuel and electricity consumption for each piece of equipment. Additionally, plant activities that result in direct or indirect GHG emissions, as defined by the LGCC, were recorded.

Selection of emission factors: Emission factors were sourced from the IPCC (Intergovernmental Panel on Climate Change) [6], AP-42 [10], INECC (National Institute of Ecology and Climate Change) [7] for fuels, CRE (Energy Regulatory Commission) [7] for electricity, and intersecretarial agreements published by SEMARNAT (Secretariat of Environment and Natural Resources) for the calculation of GHG and compound emissions [9].

Calculation of GHG emissions: Emissions were calculated using Microsoft Excel and the formula:

$$E = AD \times EF$$

where E is the emission in CO_2 equivalent, AD is the activity data (e.g., kilograms, tons, liters, or units used, consumed, or produced), and EF is the emission factor for the activity. The resulting data set was compiled into a database, which will serve as a baseline for future emission inventories.

The inventory comprehensively considered all stages from material reception to final product shipment, ensuring alignment with national and international standards for GHG accounting.

3. Results

Initially, direct emissions resulting from fuel combustion and chemical reactions were identified. These include emissions from internal combustion equipment and utility vehicles. In addition, indirect emissions associated exclusively with electricity consumption in production processes and administrative operations were accounted for (see Table 1).

Diesel consumption is primarily associated with steam generation in the boiler, which is essential for agrochemical production processes. LP (Liquefied Petroleum) gas-powered forklifts are used for handling raw materials, as well as for the shipping and storage of finished products. Additionally, an auxiliary utility vehicle powered by regular gasoline (Magna) is used for procurement activities. It is important to note that some months appear to show no fuel consumption due to the use of a credit-based payment system, in which transactions are not recorded monthly. Electricity consumption is attributed to both administrative operations and machinery used in production processes. A notable peak in electricity usage occurred in July, corresponding to increased demand for products during that period (see Table 2).

Table 1 Identification of sources of GHGs.

Direct emissions				
Source	Capacity	Fuel	Fixed source	Mobile source
Boyler Cleaver Brooks	50 CC	Diesel	X	
Heater Rheem 1	300 BTU	LP Gas	X	
Heater Rheem 2	300 btu	LP Gas	X	
Forklift Yale #25	5 t	LP Gas		X
Forklift Yale #45	5 t	LP Gas		X
Forklift Clarck #42	2.5 t	LP Gas		X
Forklift Clarck #70	2.5 t	LP Gas		X
Forklift Clarck #51	2.5 t	LP Gas		X
Forklift Clarck #73	2.5 t	LP Gas		X
Forkliftt Clarck #90	2.5 t	LP Gas		X
Forklift Clarck #91	2.5 t	LP Gas		X
Van Saveiro 2014	N/A	Gasoline		X
Indirect emissions				
Energy consumption in the plant (machinery, equipment, luminaires, etc.)	N/A	N/A	N/A	N/A

Table 2 Fuel consumption associated with direct and indirect GHG emissions.

Fuel consumption				
Month	Diesel (L)	LP gas (L)	Magna gasoline (L)	Electrical energy (MWh)
January	3,540	4,686.6	4,814.70	882.96
February	4,800	4,232	-	773.85
March	37,126	8,003.5	-	559.44
April	9,040	4,968.1	6.10	608.15
May	40,006	4,433.9	3,184.6	652.70
June	5,440	4,901.5	18.29	619.53
July	4,240	4,672.7	1,592.33	1,127.23
August	2,600	3,136.2	1,592.33	719.23
September	3,040	3,009.5	1,592.33	477.35
October	2,000	3,479.3	1,592.33	719.91
November	2,640	1,460.1	-	643.09
December	851	952.6	1,592.33	395.98

Table 3 Fossil-fuel emission factors for direct emissions calculation.

Fuel	Density (kg/L)	Carbon content (% weight)	Net calorific value (MJ/kg)	Emission factor (kg/L)	Uncertainty
Magna	0.723	85.52	39.53	2.265	1.35%
Diesel	0.833	85.95	45.92	2.625	0.66%
LP gas	0.525	1.96	81.99	1.58	1.34%

Table 3 presents the emission factors used for calculating direct emissions resulting from the oxidation of fossil fuels, as established by INECC [6].

Indirect emissions resulting from electricity consumption were calculated using an emission factor of **0.438 t CO_2e/MWh**, as established by the National Energy Regulatory Commission [9]. **Table 4** presents the monthly GHG emissions, categorized by source type. Direct emissions result from the combustion of fossil fuels such as diesel, LP gas, and gasoline, while indirect emissions are associated with electricity consumption.

Table 4 GHG emissions by source type–monthly breakdown.

Emissions (t CO_{2eq})				
Month	Diesel	LP gas	Magna gasoline	Electrical energy
January	9.29	7.40	10.91	465.32
February	12.6	6.69	-	407.82
March	97.46	13.28	-	294.82
April	23.73	7.85	0.01	320.50
May	105.02	7.01	7.21	343.97
June	14.28	7.74	0.04	326.49
July	11.13	7.38	3.61	594.36
August	6.83	4.96	3.61	379.03
September	7.98	4.76	3.61	251.56
October	5.25	5.50	3.61	379.39
November	6.93	2.31	-	338.91
December	2.23	1.51	3.61	208.68
Total	302.73	76.39	36.22	4,310.85

Of the total emissions released by the plant into the atmosphere, 9% correspond to direct emissions, while 91% are attributable to indirect emissions. Emission patterns varied throughout the year, with January, May, and July recording notably higher values. These peaks may be associated with increased demand for agrochemical products and the prevailing climatic conditions during those months.

4. Conclusions

The GHG inventory enables the measurement, monitoring, and quantification of GHG emissions, which is essential for understanding and addressing the impact of human activities on climate change.

At the agrochemical production plant, total direct emissions from fossil fuel combustion amounted to 415.34 tons of CO_2 equivalent, while total indirect emissions from electricity consumption reached 4,310.85 tons of CO_2 equivalent.

This data enhances transparency in GHG management, allowing both companies and regulatory authorities to be accountable for their mitigation efforts and to comply with environmental regulations and international commitments.

Total GHG emissions peaked in July, coinciding with the onset of the rainy season and increased production demand. Effective management and future reduction of emissions will depend on the implementation of a comprehensive transition plan toward cleaner energy sources at the plant.

The plant's layout and available space are conducive to installing solar panels to partially supply operational energy needs. Additionally, transitioning to biofuels for forklifts, vehicles, and machinery, optimizing industrial processes to improve efficiency and reduce energy consumption, and training employees on sustainable practices and carbon footprint reduction are recommended strategies.

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