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Carbon Footprint for Industry -Al-Rasheed Vegetable Oil Factory

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Abstract

This is a comprehensive study to calculate the carbon footprint of the Al-Rasheed vegetable oil factory in gaining a clear understanding of the environmental impact and identifying opportunities for emission reduction and sustainability improvement and to provide an overview of the key elements and objectives of the current study. Utilizing industry-standard calculation methodologies and emission factors specific to Al-Rasheed Factory and geographic location, we analyzed the collected data to quantify Al-Rasheed carbon emissions across only scope 1(Direct GHG Emissions via the burning of fossil fuels) measured by using the latest IPCC 2021 version 1.02 GHG Protocol and the SimaPro version 9.5 LCA software was used for modeling the processes analyzed in this study IPCC 2021 with a timeframe of 20 years(GWP100) and by using the conventional emission factor. It is confirmed that calculating carbon footprint applying Sima Pro software is more realistic than using the emission factor conversion equation. The factory consumed a total amount of diesel while it was operational equal to 17472000 liters, which is equivalent to 8,476,837 kg CO2-eq carbon footprint. This is significant amounts of GHG gases emitted to the atmosphere for more than 50 years. Thus, it was concluded that the Al-Rasheed vegetable oil factory is a major source of air pollution for the city Baghdad especially with the fact that it is now located in residential area. Therefore, it is recommended that mitigation measures should be considered seriously when the Al-Rasheed vegetable oil factory will be operational again.

Keywords: Al-Rasheed Vegetable Oil Factory, Carbon Footprint, Emission Factor, Scope 1, SimaPro.

Introduction

Al Rasheed Vegetable Oil Factory is one of the leading oil production factories in Iraq. The main output in this factory is vegetable oils, fats, laundry soaps, and detergents. There are two main sections in this factory the first division produces oil and fats directly from the sources of different plant sources available in the nearby area. The second division is producing soaps and detergents in different forms by using oil and fats (Using both vegetable and animal fats). Detergent is produced in liquid and powdered form; at the same time, it produces toilet soap and laundry soap.

Anthropogenic carbon emissions play a crucial role in global climate change by causing an imbalance in carbon cycle rainfall change and a shift in the earth's energy balance towards warming. Industrial processes are the largest contributor to the emissions of air-polluted gasses [1-4].

The major categories of footprints developed to date are carbon, ecological, and water footprints, forming the so-called "footprint family" [5-7]. Many people use the phrases energy footprint and carbon footprint interchangeably because most of a person, product,

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or organization's emissions come from using fossil fuel-based energy [8,9]. The term carbon footprint was introduced in the 1990s by Canadian environmentalist William Rees [5,2]. The carbon footprint was most probably derived from the global warming potential (GWP), an indicator often reported in life cycle LCA studies and was first defined in the scientific literature [10], Carbon footprint reporting or disclosure to the third party or public can be part of compliance with the legislative requirements, carbon trading, improvement of brand image, or as a part of corporate social responsibility, legislative measures have been taken to calculate and diminish the carbon footprint of organizations, cities, and products, and thus is becoming a common component of policy development [7,11]. Some corporations have recognized that a carbon-constrained economy may arrive soon and therefore are moving to quantify their carbon footprint and reduce emissions [12, 13].

The estimate of the carbon footprint of crude oil production in Iraq, considers the associated gas, a part of the production lifecycle to propose an alternative energy utilization solution that can reduce the energy waste as well as the carbon footprint. The energy estimation is then used to substitute the equivalent generated electricity from fossil fuel [14]. Carbon footprint is the sum of all the GHG emissions directly or indirectly caused by a company, organization, process, product, or person, and any activity over a given period, usually measured in terms of tons or kilograms of carbon dioxide equivalents (CO_2e) [11, 15, 16]. It comprises carbon dioxide, methane, nitrous oxide, and fluorinated gas emissions based on 100 years of forcing potential [17].

The carbon footprint accounts for both direct and indirect emissions. Direct emissions, also known as scope 1 emissions, are greenhouse gases emitted by sources owned or controlled by the entity, such as emissions from the use of fossil fuels for heating or transportation. Indirect emissions, also known as scope 2 and scope 3 emissions, are caused using purchased electricity, transportation, waste management, and other value-chain activities [18,19].

The primary objective of this study is to accurately measure and quantify Al-Rasheed Vegetable Oil Factory's factory greenhouse gas emissions, specifically focusing on carbon dioxide (CO2) emissions, by conducting a comprehensive carbon footprint assessment. This will provide insights into which activities contribute most significantly to the Al-Rasheed Vegetable Oil Factory's carbon footprint and help prioritize reduction strategies. The assessment will establish a baseline for Al-Rasheed Vegetable Oil Factory's carbon footprint, serving as a reference point against which future progress can be measured. The assessment will ensure that Al-Rasheed Vegetable Oil Factory remains compliant with applicable environmental regulations, this can improve the brand reputation of the factory.

Materials and Methods

Methodology

Al-Rasheed Vegetable Oil Factory is in the southern part of Baghdad on the left bank of Tigris. It is nearer to the Al Wahda water project and power station in the southern part of Baghdad. The factory is 99452 square meters [20] in an industrial area near Tigris. Many industries are located near this factory and depend on Tigris for industrial usage.

The calculation methodology for the carbon footprint assessment follows internationally recognized standards and guidelines [21], ensuring accuracy, credibility, and comparability. The methodology includes the following steps [18, 22].

Scope Definition:

Defining the scope of the assessment is based on the company's operational boundaries (Fig. 1), including direct GHG Emissions via the burning of fossil fuels (Scope 1), indirect emissions from purchased electricity (Scope 2), and indirect GHG Emissions from the materials and energy carrier life cycle activities in the supply chain that are produced outside the boundaries (Scope 3).

Clear outline of the emission sources and categories are to be considered within each scope. Due to the rather limited data, we will deal with Scope 1 only.

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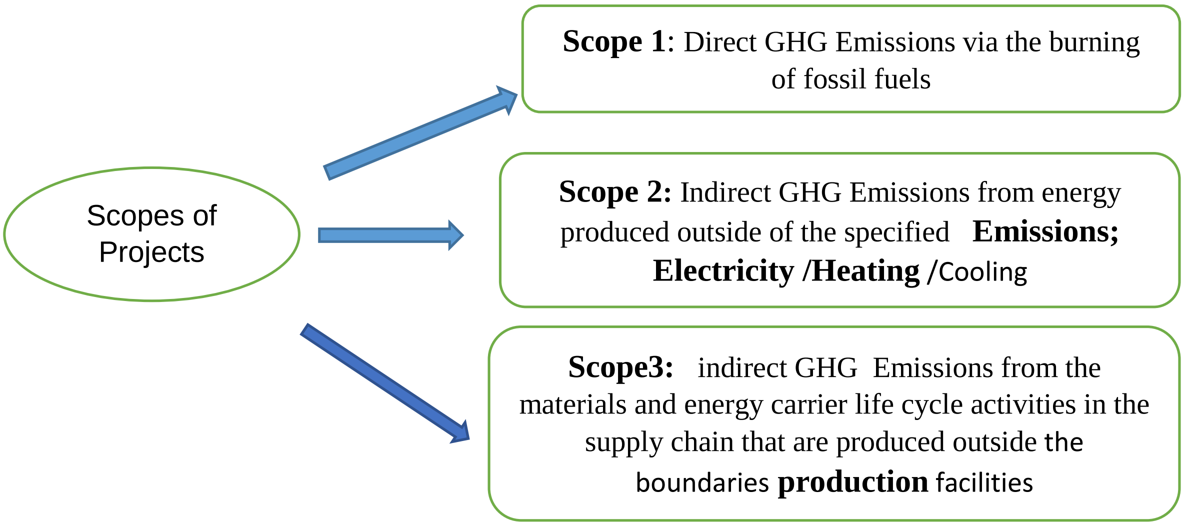

Figure 1. Direct and indirect GHG emissions according to their scopes of Al-Rasheed Vegetable Oil Factory

Data Collection:

Activity data of comprehensive and reliable data on energy consumption, fuel use (diesel and gasoline), transportation, waste generation, and other relevant activities were collected from bills, data sheets, and personal communication and Ensured data quality and accuracy through validation and verification procedures.

Emission Factors:

Appropriate emission factors specific were selected to the vegetable oil industry, geographic location, and fuel sources, and recognized emission factor databases, industry-specific sources, or emission factors provided by relevant experts according to the latest emission factors to reflect the most accurate and up-to-date information available [23].

Calculation Formulas:

Calculation of direct emissions (Scope 1) by multiplying activity data (e.g., fuel consumption) with respective emission factors for each greenhouse gas (e.g., carbon dioxide, methane, nitrous oxide) as the below equation[24,25].

Gasoline Footprint = Emission Factor (2.75776 Kg CO_2 eq) X Annual Fuel Consumption

Calculation Tools:

In the present study, the Carbon Footprint was measured using the latest IPCC version 1.02 GHG Protocol. The specific focus of this study was on the Global Warming Potential (GWP)/Carbon Footprint. Finally, the SimaPro version 9.5 LCA software was used for modeling the processes analyzed in this study. IPCC 2021[21] is the successor of the IPCC 2013 method, which was developed by the Intergovernmental Panel on Climate Change. It contains the Global Warming Potential (GWP) climate change factors of IPCC with a timeframe of 100 years (GWP100) ,This method is based on the final government distribution version of the IPCC report 'AR6 Climate Change [21,26].

The most relevant emissions factors of IPCC 2021 were used during the carbon footprint calculation. By default, the IPCC 2021 LCA (emission) factors were used for greenhouse gas reporting, which are globally recognized and widely used by international organizations to report on greenhouse gas emissions. The SimaPro LCA emission factors database is considered one of the most comprehensive and reliable of its kind and is updated on an annual basis [27]. An attempt to compare the data obtained from SimaPro software with that of the conventional calculation using emission factor.

Upstream processes for the inputs consumed in the manufacture of oil were followed/obtained from Eco-invent Database version 3.9.1, mostly the global average data for the upstream processes were considered in this study.

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Data Quality Assurance:

We implemented measures to ensure the accuracy and reliability of the collected data. This involved data validation checks, cross-referencing with multiple sources, and verification with supporting documents [28].

Results and Discussion

In Iraq, demographic sprawl led to the shift of some of industrial sites into residential places, particularly in Baghdad. The government is facing the fact that most of the industries that were founded during the previous century are now located in neighboring residential areas. The Al-Rashid Vegetable Oil Factory is no exception[20]. The manufacture of fit-to-be-eaten vegetable oils started in 1940 when the first plant (Al-Rasheed) was established to generate it, and the manufacturing facility increased till it finished 900 tons per day. The effect of fossil combustion on the carbon footprint in the Eastern Karrada region, Baghdad was studied by[27]. These authors identified the main causes of carbon increment and suggested several solutions to reduce the carbon footprint. They reported an increase in emissions resulting from fuel combustion since most agricultural areas in the region are being converted to residential, educational, commercial, and industrial. The increase in the population and the increase in the number of private cars, which in turn caused heavy traffic congestion, in addition to the absence of sustainable public transport, the increase in private transportation.

To make the Sima Pro software calculations recognizable and adaptable in Iraq, we compared it with the conventional conversion factor method[23,24]. Although the set of values appeared highly correlated (Fig. 2). However, (Table 1) shows that the Sima Pro data is at least an order of magnitude lower than that calculated using the direct conversion factor. This is an important finding as many researchers have no access to Sima Pro software, therefore they should be cautioned of this fact.

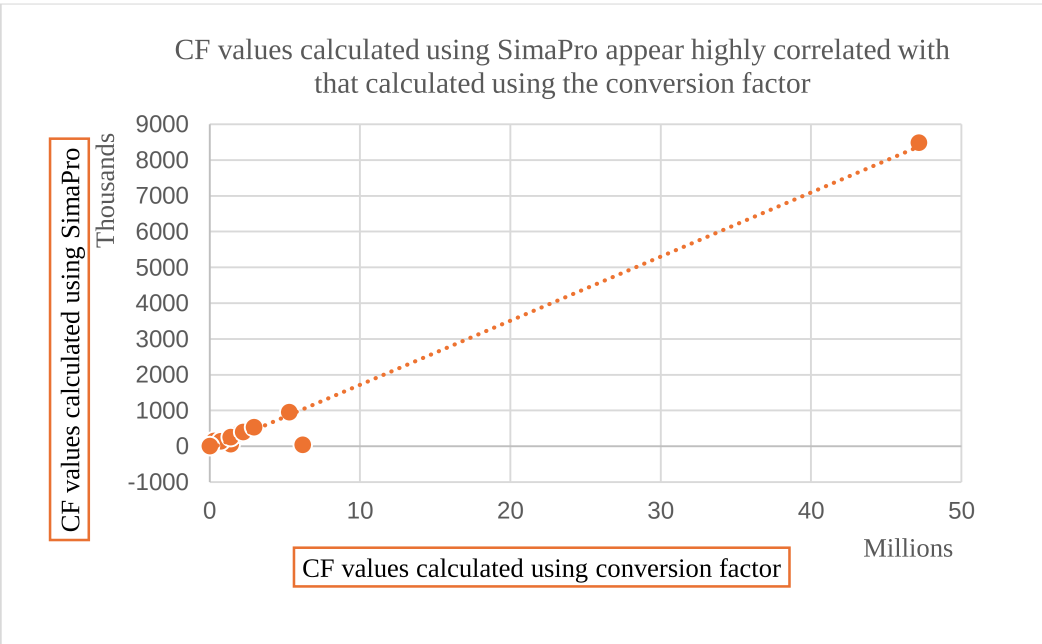

Figure 2. Correlation of Carbon Footprint Calculated values using SimaPro software with values obtained using conventional Conversion Factor

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Table 1. Comparison of Carbon Footprint Calculated values for Al-Rasheed Vegetable Oil Factory using SimaPro software versus values obtained using conventional Conversion Factor*.

Number	Amount of consumed f (Liters)	CF calculated values using SimaPro Software (kg CO_2-eq)	CF calculated values using Conversion Factor (kg CO_2-eq)
1	17472000	8476837	47174400
2	706000	34228	6177600
3	1956000	948987	5281200
4	1001000	485652	2826900
5	765000	380856	2008800
6	84000	408510	2201400
7	112000	54339	1401300
8	725000	351746	1957500
9	293500	142397	292450
10	275000	133421	742500
11	519000	251802	1401300
12	824000	399778	2224800
13	1096000	531743	2959200
14	2373	1078	6407
15	418	192	1129

***= CF conversion factor for diesel is 2.75776 Kg CO_2 eq (International Panel on Climate Change, IPCC 2012)**

Basing on the working status and production capacity, the Al-Rasheed factory experienced four phases. Accordingly, between 1950 to 2003 the factory was working at full capacity, while from 2004 to 2014 the factory was producing detergent and carrying out oil packing, between 2014 to 2021 the factory was producing detergent only, however, it was stopped completely in 2022. To facilitate the decision maker, we shall attempt to address the four phases from an environmental view and carbon footprint.

Phase 1. Full operation

The present study managed to obtain diesel consumption data when the Al-Rasheed vegetable oil factory was fully operational i.e. producing oil and detergent as well as packing the products. An example that we chose is the most recent full production, the year 2003. Records showed that the total amount of diesel consumed was 17472000 liters, which is equivalent to 8,476,837 kg CO_2-eq carbon footprint as calculated by Sima Pro software (Table 2 and Fig. 3). This is an appreciable number of pollutants that may have affected the overall air quality in Baghdad over the factory working years (1950-2003)[28-30]. A new global study has revealed the extent of greenhouse gas (GHG) emissions caused by vegetable oil production, highlighting the need for more sustainable growing solutions. Across all oil crop systems, median GHG emissions were 3.81 kg CO_2e per kg of refined oil[31]. Therefore, mitigation should be considered seriously when the factory should be perianal again.

Table 2. Total Annual CF of Al-Rasheed Vegetable Oil Factory Fully Operational (2003)

Damage category	Unit	Total	Consumed Diesel (Liter) 17472000 (2003)
CF(GWP100)	kg CO2-eq	8476837.376	8476837.376

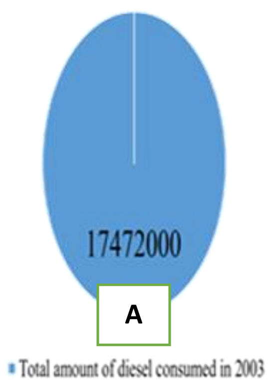

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Figure 3. Al-Rasheed Factory - Operational in Total A- Monthly consumption of Diesel (Liters) B- Annual Carbon footprint

Phase 2. Detergent production and packing

When Al-Rasheed Vegetable Oil Factory during 2004 – 2013 was producing detergents and packing oil only, we selected the period 2010-2014 as we believe that it reflects accurately phase 2. The amount of consumed fuel was reduced considerably in comparison to phase 1. The Al-Rasheed factory operation period (phase 2) depended mainly upon the availability of raw materials this was highlighted in 2011 when the raw material was abundant. Thus, the factory consumed more than 1956000 liters of diesel with a carbon footprint (of 948986.6019) in contrast to 2010,2012 and 2013 when the raw materials were scarce thus the Al-Rasheed Vegetable Oil Factory consumed 706000, 1001000, and 765000 liters of diesel respectively with carbon footprint (342527.8839, 485652.1414 and 380856.075 respectively) (Table 3 and Figs. 4,5). Although these values are an order of magnitude lower than phase 1, they reflect a big amount of CO_2 being emitted into the atmosphere of Baghdad. Carbon, specifically carbon dioxide (CO_2), is a greenhouse gas that contributes to global climate change. When CO_2 is released into the atmosphere through human activities such as burning fossil fuels, it traps heat in the Earth's atmosphere and contributes to the warming of the planet[21].

Table 3. Total Annual CF of Al-Rasheed Vegetable Oil Factory during (2010 -2013)

Damage category	Unit	Total	Consumed Diesel (Liter) (706000) 2010	Consumed Diesel (Liter) (1956000) 2011	Consumed Diesel (Liter) (1001000) 2012	Consumed Diesel (Liter) (765000) 2013
CF(GWP100)	kg CO2-eq	2158023	342527.8839	948986.6019	485652.1414	380856.075

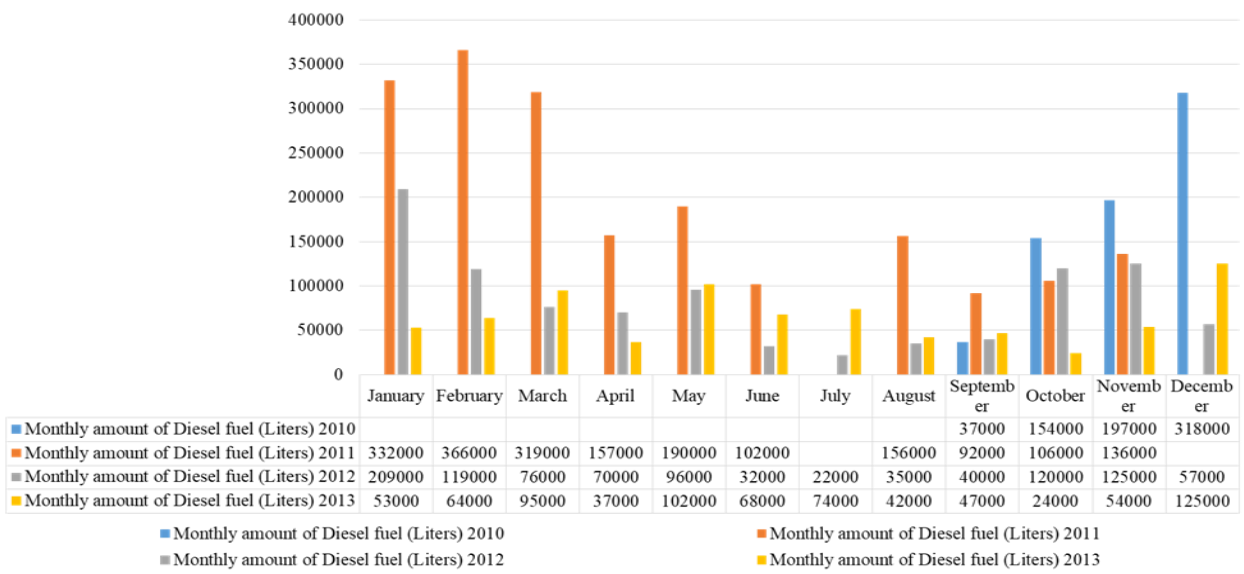

Figure 4. Monthly use of Diesel (Liters) of Al-Rasheed Vegetable Oil Factory during Oil packing and Detergent production between 2010 -2013

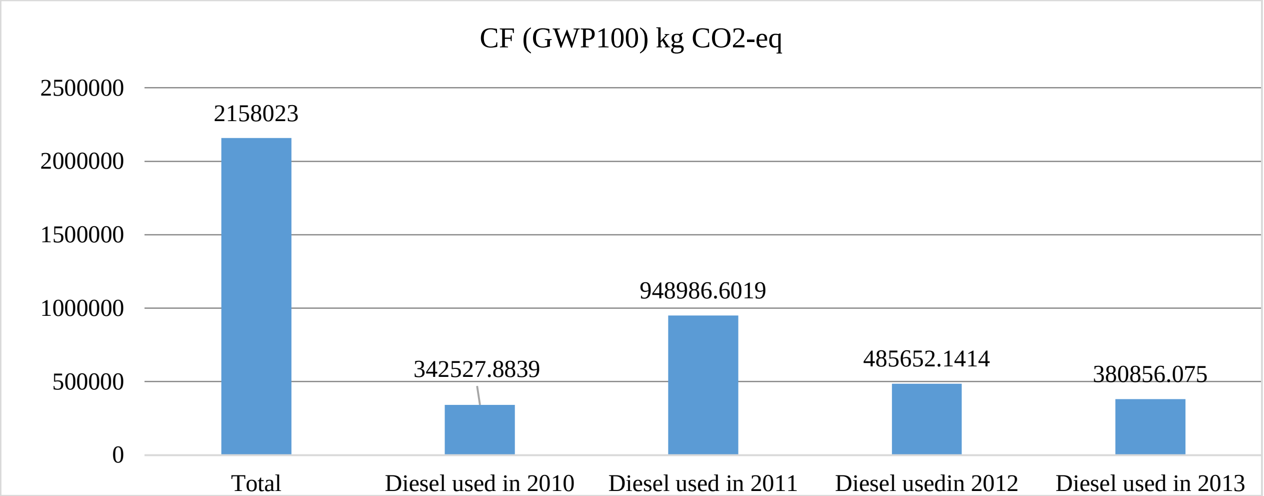

Figure 5. Annual Carbon footprint of Diesel used by Al-Rasheed Vegetable Oil Factory during Oil packing and Detergent production between 2010 -2013

Phase 3. Detergents production only

During this period planting oily seeds was very limited in Iraq, that was due to desertification, lack of freshwater, and climate change. Furthermore, oil raw materials imported including purchasing and transportation were so costly to cope with the competition of the imported vegetable oil. Therefore, the Al-Rasheed factory has been shifted from the production of vegetable oil to the production of detergents from 2014 to 2021.

The total value of carbon footprint was 2273735.025 kg CO2-eq during eight years between 2014 and 2021 as calculated using Sima Pro software. The annual CF values varied during these periods depending solely on the amounts of fuel that were consumed, the highest value of CF 531743.0039 kg CO2-eq was recorded in 2021, while the lowest value was 54338.70113 in 2015 (Table 4, Figs. 6,7).

Table 4. Total Annual CF of Al-Rasheed Vegetable Oil Factory during (2014 -2021)

Damage category	**Unit**	**Total**	**Consumed Diesel (Liter) 842000 2014**	**Consumed Diesel (Liter) 112000 2015**	**Consumed Diesel (Liter) 725000 2016**	**Consumed Diesel (Liter) 293500 2017**
CF(GWP100)	kg CO2-eq	2273735.0250	408510.5924	54338.7011	351746.0564	142396.5070
			Consumed Diesel (Liter) 275000 2018	Consumed Diesel (Liter) 519000 2019	Consumed Diesel (Liter) 824000 2020	Consumed Diesel (Liter) 1096000 2021
			133420.9180	251801.6597	399777.5869	531743.0039

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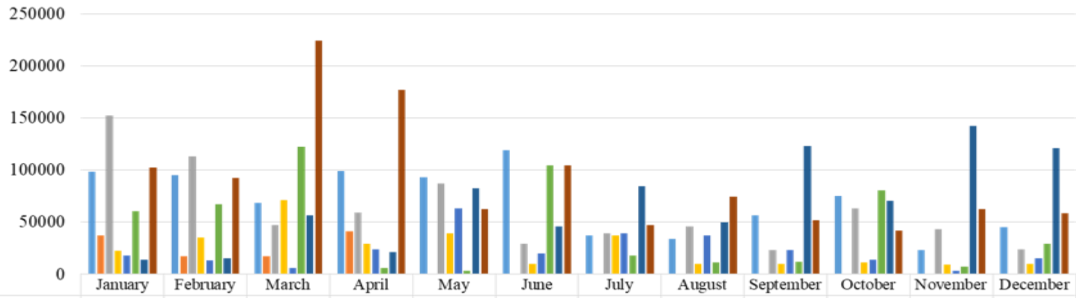

	January	February	March	April	May	June	July	August	September	October	November	December
Quantity of Diesel (Liters) 2014	98000	95000	68000	99000	93000	119000	37000	34000	56000	75000	23000	45000
Quantity of Diesel (Liters) 2015	37000	17000	17000	41000								
Quantity of Diesel (Liters) 2016	152000	113000	47000	59000	87000	29000	39000	46000	23000	63000	43000	24000
Quantity of Diesel (Liters) 2017	22500	35000	71000	29000	39000	10000	37000	10000	10000	11000	9000	10000
Quantity of Diesel (Liters) 2018	18000	13000	6000	24000	63000	20000	39000	37000	23000	14000	3000	15000
Quantity of Diesel (Liters) 2019	60000	67000	122000	6000	3000	104000	18000	11000	12000	80000	7000	29000
Quantity of Diesel (Liters) 2020	14000	15000	56000	21000	82000	46000	84000	50000	123000	70000	142000	121000
Quantity of Diesel (Liters) 2021	102000	92000	224000	177000	62000	104000	47000	74000	52000	42000	62000	58000

Quantity of Diesel (Liters) 2014 Quantity of Diesel (Liters) 2015 Quantity of Diesel (Liters) 2016 Quantity of Diesel (Liters) 2017
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Figure 6. Monthly use of Diesel (Liters) of Al-Rasheed Vegetable Oil Factory during Oil packing and Detergent production between 2014-2021

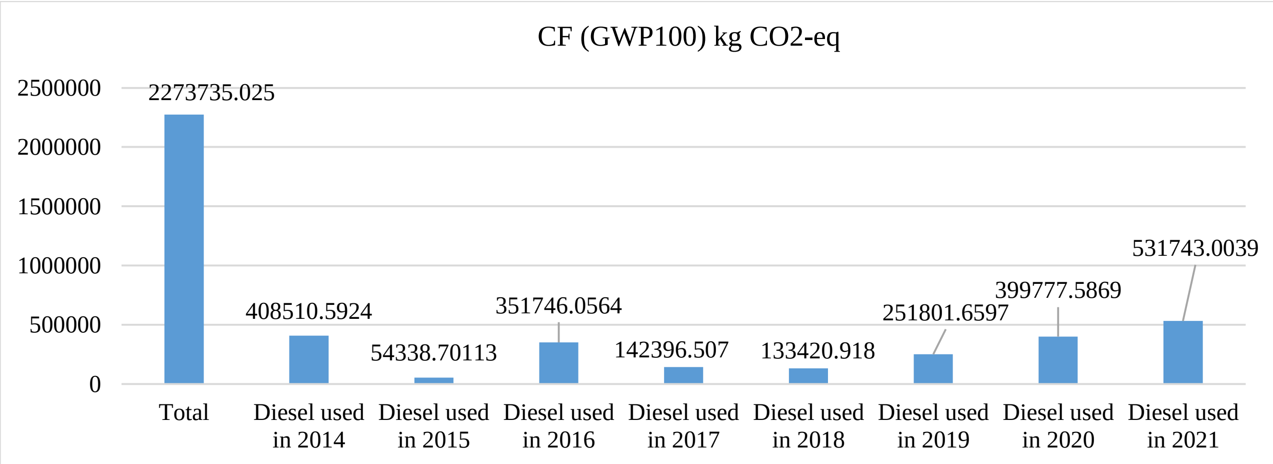

Figure 7. Annual Carbon footprint of Diesel (Liters) of Al-Rasheed Vegetable Oil Factory during Oil packing and Detergent production between 2014-2021

Phase 4. At Halt

The year 2022 experienced the complete stoppage of the Al-Rasheed vegetable oil factory which might be due to a lack of raw materials and/or that the factory machines went out of order. The present study focused on fuel consumption in the year 2022 and confirmed the data by the data of fuel consumption in the first quarter of 2023. During this period, both diesel and gasoil were used as fuel, with modest consumption mainly for vehicles and truck movements within the factory site. The modest carbon footprint value for that period was 1269.1404 can be considered as a benchmark value (Table 5 and Figs. 8,9). This value should be considered if the factory is to be functioning again in the future[32].

In order to suggest a reasonable benchmark value for future considerations the present study consulted available international standards including: GHG Protocol, which was created by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)[33] , The International Organization for Standardization (ISO): ISO 14064-1:2018 , ISO 14064-2,3 :2019[34], The Carbon Trust Standard[35], PAS 2050, Science-Based Targets (SBTs): which offer detailed instructions for companies to assess and control their GHG emissions[36], provides guidelines for both product life cycle accounting and company accounting (Scope 1, 2, and 3 emissions), instructions for measuring, recording, and reporting

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GHG emissions and removals, guidelines for the validation and verification of GHG statements, a strong framework for evaluating carbon footprints[34-36], guidance on assessing the life cycle greenhouse gas emissions of products and services and provides guidelines for setting emissions reduction targets aligned with the goals of the Paris Agreement [37]. However, it is important to note that the choice of carbon footprint standard may be dependent on a range of factors, e.g., organization sector, geographic location, data objectives, and stakeholder requirements[16]. It is the standard or framework that best fits the factory-specific requirements and industry practices that they often choose.

Table 5. Total Annual CF of Al-Rasheed Vegetable Oil Factory during (2022 -2023)

Damage category	Unit	Total	Consumed Diesel (Liter) (1106.14) 2022	Consumed Gasoil (Liter) (1267.11) 2022	Consumed Diesel (Liter) (169.39) 2023	Consumed Gasoil (Liter) (248.64) 2023
CF(GWP100)	kg CO_2-eq	1269.1404	462.9183	614.7066	70.902	120.6125

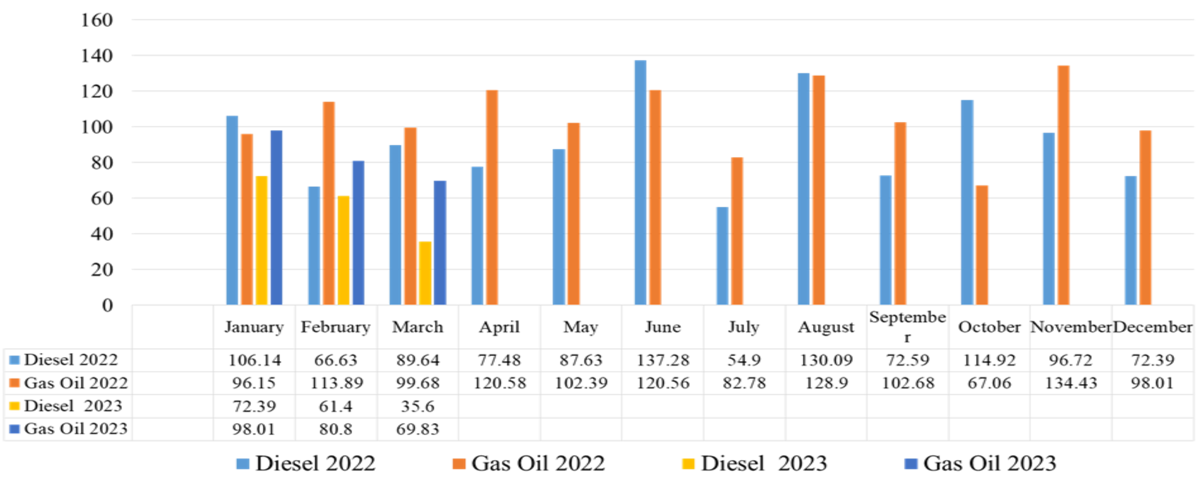

Figure 8. Monthly of Diesel and Gasoline (Liters) used during the halt of Al-Rasheed Vegetable Oil Factory between 2022 – 2023

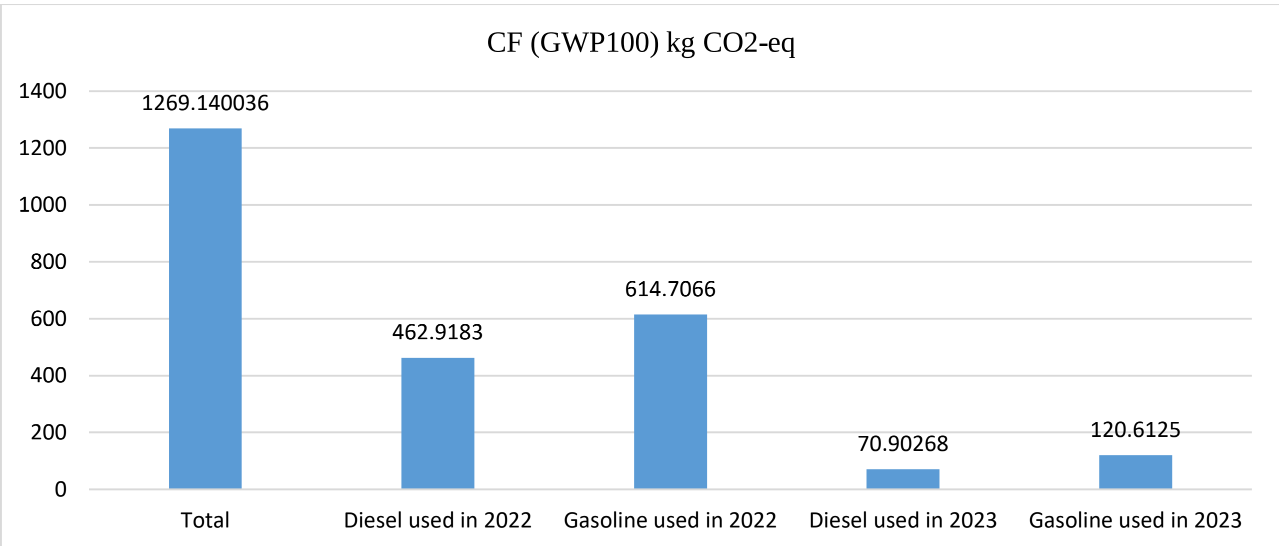

Figure 9. Annual Carbon footprint of Diesel and Gasoline used during the halt of Al-Rasheed Vegetable Oil Factory between 2022-2023

Conclusion

In the light of the above discussion, it may be thus concluded that:

1- Calculating carbon footprint of the Al-Rasheed vegetable oil factory is an essential step toward understanding and addressing its environmental impact.
2- Al-Rasheed Vegetable Oil Factory is a major source of air pollution in Baghdad specially with the fact that it is now located in the residential area.
3- Carbon footprint values calculated using Sima Pro are at least an order of magnitude lower than those calculated using the direct conversion factor.

Recommendations

The current study recommends the following:
1- Mitigation of emitted gases should be considered seriously when the Al-Rasheed vegetable oil factory will be operational again.
2- Sima Plot software should be used to calculate carbon footprints.

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Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at University of Baghdad.

Authors' Contribution Statement

E. M. A. designed and ratified and performed the experiments, analyzed and interpreted the data, contributed reagents, materials, analysis tools, or data and wrote the paper. J. S. A. approved and designed the experiments, analyzed and interpreted the data.

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البصمة الكربونية للصناعة-مصنع الرشيد للزيوت النباتية

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الخلاصة

تمثل الدراسة الحالية نهجًا منظمًا وعلميا لحساب البصمة الكربونية لمصنع الرشيد وذلك بتحديد نطاق العمل بوضوح، بما في ذلك الحدود التنظيمية ومصادر الانبعاثات المحددة التي تم تقييمها من خلال إجراء تحليل شامل يغطي الانبعاثات المباشرة المرتبطة بعمليات المصنع وسلسلة القيمة الخاصة بها. تم استخدام منهجيات الحساب الحديثة والمعتمدة من قبل المنظمات العالمية والمتوافقة مع معايير الصناعة وعوامل الانبعاثات الخاصة بمصنع الرشيد والموقع الجغرافي للمصنع. حللنا خلال هذه الدراسة البيانات التي زودتنا بها إدارة مصنع الرشيد لتحديد انبعاثات الكربون من المصنع عبر النطاق 1 (انبعاثات الغازات الدفيئة المباشرة عن طريق حرق الوقود الأحفوري) قمنا وبالتعاون مع عددا من المعاهد الدولية بحساب البصمة الكربونية ونمذجة العمليات باستخدام أحدث بروتوكول معتمد عالميا. IPCC) 2021) الإصدار 1.02مع إطار زمني مدته100 عاما (GWP100). من خلال التطبيق الدقيق لبرنامج SimaPro software 9.5 LCA. وعند مقارنة النتائج اثبتت الدراسة ان دقة نتائج البرمجيات الحديثة باستخدام برنامج Sima Pro تفوق بكثير تلك الناتجة عن احتساب البصمة الكربونية من خلال تطبيق معادلة معامل تحويل الوقود، لذلك توصي الدراسة استخدام طرق الحسابات الحديثة والبرمجيات المعتمدة دوليا للتوصل الى النتائج المنشودة. اثبتت نتائج الدراسة ان المصنع يستهلك كمية إجمالية من الديزل أثناء تشغيله تساوي 17472000 لتر، أي ما يعادل 8,476,837 كجم من انبعاثات الكربون CO2-eq. هذه كميات كبيرة من الغازات الدفيئة المنبعثة في الغلاف الجوي عندما كان المصنع يعمل لأكثر من خمسين سنة. وهكذا استنتجت الدراسة ان المصنع هو مصدر رئيسي لتلوث الهواء لمدينة بغداد خاصة انه يقع الان في منطقة سكنية. لذلك، توصي الدراسة بالنظر بجدية في تدابير التخفيف للحد من تلك الملوثات إذا ما اعيد المصنع للعمل ثانية.

الكلمات المفتاحية: مصنع الرشيد للزيوت النباتية، البصمة الكربونية، عامل الانبعاث، مجال 1، SimaPro.