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Araştırma Makalesi / Research Article

Investigation of Environmental Impacts of Ready Concrete Production Facilities

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Abstract

The carbon emission value resulting from production activities in the ready-mixed concrete and concrete products production facility in Muğla province was calculated. The carbon emission value has been determined for 2023 according to the emission sources in the facility. Emission sources in the facility were the use of fuel for personnel transfer and product shipment, the use of electricity, natural gas, and water needed in the production process; wastewater, waste oil, and paper cardboard as wastes. The factors were classified according to ISO 14064:2018 and GHG Protocol. IPCC Tier 1 methodology was used in the calculation. DEFRA and IPCC national databases were used for emission factors while the Turkish Republic Ministry of Energy and Natural Resources Energy Efficiency and Environment Department Turkey National Electricity Grid Emission Factor was used for electricity emission factor data. Numerous actions can result in the production of the three fundamental gases CO_2, CH_4, and N_2O. The global warming potentials of the three basic gases (CO_2, CH_4, and N_2O) were used to calculate the results in tCO_2e in the carbon emission. The CO_2 emission value of electricity consumption from the use of machinery, equipment, and installations in the facility in 2023 was determined as 177.007 tCO_2. The total emission value resulting from fuel consumption was calculated as 4482.649 tCO_2. The total CO_2 emission value resulting from natural gas used in the production process was determined as 508.1128 tCO_2. CO_2 emissions resulting from water consumption were calculated as 3.594 tCO_2. The CO_2 emission values resulting from the formation of wastewater, waste oil, and paper cardboard waste were determined as 0.1077, 0.0117, and 0.00192 tCO_2, respectively. By evaluating all activity data during the production of ready-mixed concrete and concrete products, the total CO_2 emission value of the facility was 5171.484 tCO_2. The activity that contributes the most to the CO_2 emission value is fuel consumption. Fuel consumption was followed by natural gas and electricity consumption, respectively. Although the facility has low emission values, it is very important to minimize emissions to achieve the 2050 targets.

Keywords: CO_2 emission, Tier 1 method, Ready mixed concrete plant, Sustainability, Environmental management.

Hazır Beton Üretim Tesislerinin Çevresel Etkilerinin İncelenmesi

Öz

Muğla ilinde bulunan hazır beton ve beton ürünleri üretim tesisinde üretim faaliyetlerinden kaynaklanan karbon emisyon değeri hesaplanmıştır. Tesisteki emisyon kaynaklarına göre 2023 yılı karbon emisyon değeri belirlenmiştir. Tesisteki emisyon kaynakları; personel transferi ve ürün sevkiyatı için yakıt kullanımı, üretim sürecinde ihtiyaç duyulan elektrik, doğal gaz ve su kullanımı; atık olarak ise atık su, atık yağ ve kağıt kartondur. Faktörler ISO 14064:2018 ve GHG Protokolü'ne göre sınıflandırılmıştır. Hesaplamada IPCC Tier 1 metodolojisi kullanılmıştır. Emisyon faktörleri için DEFRA ve IPCC ulusal veri tabanları kullanılırken, elektrik emisyon faktörü verileri için Türkiye Cumhuriyeti Enerji ve Tabii Kaynaklar Bakanlığı Enerji Verimliliği ve Çevre Dairesi Türkiye Ulusal Elektrik Şebekesi Emisyon Faktörü kullanıldı. Çok sayıda faaliyet, üç temel gaz olan CO_2, CH_4 ve N_2O'nun oluşumuna yol açabilir. Karbon emisyonunda tCO_2e cinsinden sonuçları hesaplamak için üç temel gazın (CO_2, CH_4 ve N_2O) küresel ısınma potansiyelleri kullanıldı. Tesiste 2023 yılında makine, ekipman ve tesisatların kullanımından kaynaklanan elektrik tüketimine ait CO_2 emisyon değeri 177.007 tCO_2 olarak belirlenmiştir. Yakıt tüketiminden kaynaklanan toplam emisyon değeri 4482,649 tCO_2 olarak hesaplanmıştır. Üretim sürecinde kullanılan doğalgazdan kaynaklanan toplam CO_2 emisyon değeri 508,1128 tCO_2 olarak belirlenmiştir. Su tüketiminden kaynaklanan CO_2 emisyonu 3,594 tCO_2 olarak hesaplanmıştır. Atıksu, atık yağ ve kağıt karton atığının oluşumundan kaynaklanan CO_2 emisyon değerleri sırasıyla 0,1077, 0,0117 ve 0,00192 tCO_2 olarak belirlenmiştir. Hazır beton ve beton ürünleri üretimi sırasındaki tüm faaliyet verileri değerlendirildiğinde, tesisin toplam CO_2 emisyon değeri 5171,484 tCO_2 olarak bulunmuştur. CO_2 emisyon değerine en çok katkıda bulunan faaliyet yakıt tüketimidir. Yakıt tüketimini sırasıyla doğal gaz ve elektrik tüketimi takip etmiştir. Tesis düşük emisyon değerlerine sahip olsa da, 2050 hedeflerine ulaşmak için emisyonları en aza indirmek çok önemlidir.

Anahtar Kelimeler: CO_2 emisyonu, Tier 1 yöntemi, Hazır beton santrali, Sürdürülebilirlik, Çevre yönetimi.

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1. Introduction

1.1. Background

Global climate change has begun due to greenhouse gases created as a result of the increase in raw material needs and production that started with the Industrial Revolution. Human activities, the decrease in green areas, and the increasing population significantly affect the release of greenhouse gases into the atmosphere. The capacity of the radiation from the sun to hold heat in the atmosphere also increases with the increase in greenhouse gases. This negative cycle gradually causes global warming. Global warming causes negative weather changes, namely climate change. Increasing floods, hurricanes, unusual precipitation and temperatures, impacts on living things, and the resulting increase in deaths are indicators of climate change.

The climate change depend on greenhouse gas concentrations in the atmosphere and global warming. The United Nations has indicated that greenhouse gas concentrations in the atmosphere are directly linked to the average global temperature in the world and that CO_2, which makes up about two-thirds of greenhouse gases, is largely due to fossil fuels. Greenhouse gas concentrations, and with them average global temperatures, have increased steadily since the Industrial Revolution (Letcher, 2021).

The main greenhouse gas is CO_2, but there are other gases much more influential greenhouse gases such as chlorofluorocarbons (CFC_s), methane (CH_4) and nitrogen oxides (NO_x). These gases are present in the air at very low concentrations (Tuckett, 2009). Despite their current low concentrations, it has been emphasized that their production should be banned, as their accumulation in the atmosphere could be very harmful to future generations (Lu, 2013).

Global activities have been carried out to combat climate change throughout history. The United Nations Framework Convention on Climate Change, which entered into force in 1994, aims to prevent greenhouse gas accumulations in the atmosphere and dangerous human-induced effects. This practice was further developed and the Paris Agreement was signed in 2016. In this context, it was aimed to limit the global temperature increase to 1.5°C. Turkey aims to reduce greenhouse gas emissions by 41% by 2030 within the scope of the Paris Agreement. The Green Deal published in 2021 aims to reduce carbon emissions by 55% compared to 1990 by 2030 and to reduce carbon emissions to zero by 2050. In this process carried out regarding greenhouse gas, the "Regulation on Monitoring of Greenhouse Gas Emissions" was published in the official gazette by the Ministry of Environment and Urbanization in Turkey in 2012 and entered into force. In 2014, the "Communique on Monitoring and Reporting of Greenhouse Gas Emissions" was published for the monitoring and reporting of the regulation. In 2015, the "Communique on Verification of Greenhouse Gas Emissions and Authorization of Verifier Organizations" was published and entered into force. Facilities carrying out the activities included in Annex 1 of the Regulation will be subject to regular monitoring, reporting, and verification processes every year in the scope of this legislation, and monitoring plans will be submitted to the Ministry through the Environmental Information System. Therefore, monitoring of carbon emissions has become important for facilities included in the legislation.

In this study, the ready-mixed concrete production process and its environmental effects were examined in detail. In addition, the change in ready-mixed concrete production in Turkey over the years was investigated and the amount of concrete production was compared with other countries.

1.2. Carbon Footprint

For the zero carbon emission goal in 2050, first of all, it is necessary to know the amount of individual or corporate carbon emissions and thus the carbon footprint. Carbon Footprint calculates greenhouse gases released into the atmosphere due to human activities in CO_2 equivalent by various methods (TS ISO, 2019). The factors affecting carbon emission and the impact results of these factors should be evaluated and sustainable methods such as researching alternative ways to reduce energy consumption, giving priority to the use of renewable energy sources, reducing the use of fossil fuels, increasing afforestation and greening activities should be investigated. Carbon footprint calculations can be made individually or institutionally. The three important gases considered in carbon footprint calculations are CO_2, CH_4 and N_2O. Global warming potentials of these gases vary depending on their type.

The Greenhouse Gas Standard was published by the International Organization for Standardization (ISO) in 2006 in order to provide the necessary action within the scope of the environmental problems that continue to increase due to climate change. The TS EN ISO 14064-1 Greenhouse Gas Standard explains the requirements for calculating the amount of greenhouse gas emissions at the institutional level, determining the calculation limits, reporting greenhouse gas studies, verifying the calculations made, and reducing the amount of greenhouse gas emissions. The standard consists of 3 sections that address different topics (URL-1).

According to the TS EN ISO 14064-1 standard, emissions are divided into two categories: direct emissions and indirect emissions. Direct emissions are emissions that occur by an individual or institution and can be controlled by the individual or institution. Indirect emissions, on the other hand, are emissions emitted during the production phase of the product used or the raw materials supplied, unlike direct emissions. There are 3 scopes for greenhouse gas emission calculations. Scope 1, Scope 2 and Scope 3 cover direct, indirect and other indirect greenhouse gas emissions, respectively (Barrow et. al., 2013). The greenhouse gas emissions are divided into 6 categories according to ISO 14064-1

Determination of Reporting Limits for Greenhouse Gas Inventory Categories, Direct and Indirect Greenhouse Gas Emissions report (URL-2).

The Intergovernmental Panel on Climate Change was established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). Its primary mission is to conduct a comprehensive review of the state of knowledge of climate change science and to prepare recommendations. The IPCC produces comprehensive assessment reports on the state of scientific, technical and socio-economic knowledge about climate change, its impacts and future risks, and on options for reducing the rate of climate change (URL-3). There are three different methods in Carbon Footprint Calculation within the scope of IPCC Methodology and are called Tier. There are three Tier methods that represent the level of methodological complexity. Tier 1 is the basic method. Tier 2 is the medium and Tier 3 is the most challenging method in terms of complexity and data requirements (Buendia et. al, 2019). The Tier 1 calculation method is to reach the carbon equivalent amount. The CO_2e equivalent value is used in calculations. The reason is that it indicates how many times more heat retention capacity other greenhouse gases, except CO_2, have compared to the same amount of CO_2 (Civelekoğlu et. al., 2018). According to the IPCC, 6 greenhouse gases (except CO_2) are specified as CO_2e equivalents in the Kyoto Protocol. For example, to know the CO_2e value of CH_4 and N_2O greenhouse gases that are formed and calculated as a result of the activity, it is multiplied by the specified heat retention capacity. Thus, all calculations are get together in the same unit and the total value is reached. In the Tier 2 calculation method, emission factors determined by country within the scope of activity data are used instead of emission factors taken from international databases, which are mostly used in the Tier 1 method. Tier 3 requires more specific data, measurements, and evaluations comparing Tier 1 and Tier 2. The emission factors used in the Tier 3 method are facility-based values determined by the technology, models, and measurements used in the determination phase. For emission factors, there are databases established by the Intergovernmental Panel on Climate Change (IPCC) Emission Factor Database (EFDB) and the United States Environmental Protection Agency (Tanks, Speciate, LandGEM, Water) (URL-4).

1.3. Ready mix concrete production and environmental effects

A concrete batching plant is a facility where the production of ready-mixed concrete components is carried out by mixing them under control and filling them into transmixers. The plant has cement silos, aggregate bunkers, weighing bunkers, water tanks, additive tanks and mixers. The general production plant plan and typical workflow diagram of a ready mix concrete batching plant are shown in Figures 1 and 2, respectively. Ready-mixed concrete is an important building material obtained by mixing cement, aggregate (sand, gravel, crushed stone), water and, if necessary, some additives in accordance with a certain production technology, which can be shaped and gains strength by solidifying and hardening over time. In ready-mixed concrete production facilities, ready-mixed concrete is obtained by mixing aggregate materials, cement, water and some chemical additives in certain proportions according to the desired concrete properties. Ready-mixed concrete is filled into mixers and offered for sale. Additives are liquid and powder substances used for purposes such as increasing the strength, density and workability of concrete, reducing concrete water, providing fluidity, accelerating the initial setting, reducing the amount of mixing water and acting as antifreeze.

Figure 1. Typical ready mix concrete production plant

Aggregate materials such as sand and gravel are stored separately in ready-mixed concrete facilities. Cement and other filler materials are transported in bulk and by road via silobas, and the material is transported to the silos using special hoses and compressed air. Dust emissions are minimized by using filters and dust reduction systems to remove the air pressed into the silos. Aggregates and sands are stored in bunkers in front of the plant and transported to the mixing tank with a belt system.

Transfer bunkers are used to transport aggregate materials stored in the stockyard. Aggregate materials in the stockyard are sent to the transfer bunker with a loader bucket to be used in concrete production. Aggregate, cement, and water stocked in separate sections during the production phase are weighed at the same time. The weighed aggregate is transported to the transfer bunker by conveyor belt systems and discharged into the mixer tank. Then, cement and water are transferred to the boiler and mixed. The concrete resulting from the mixture is taken from the plant discharge bunker to the transmixer. The automation system adjusts the completion of the filling while the transmixer is under the discharge bunker. The completion of the filling is notified to the transmixer operator by a loud sound or a warning light warning system.

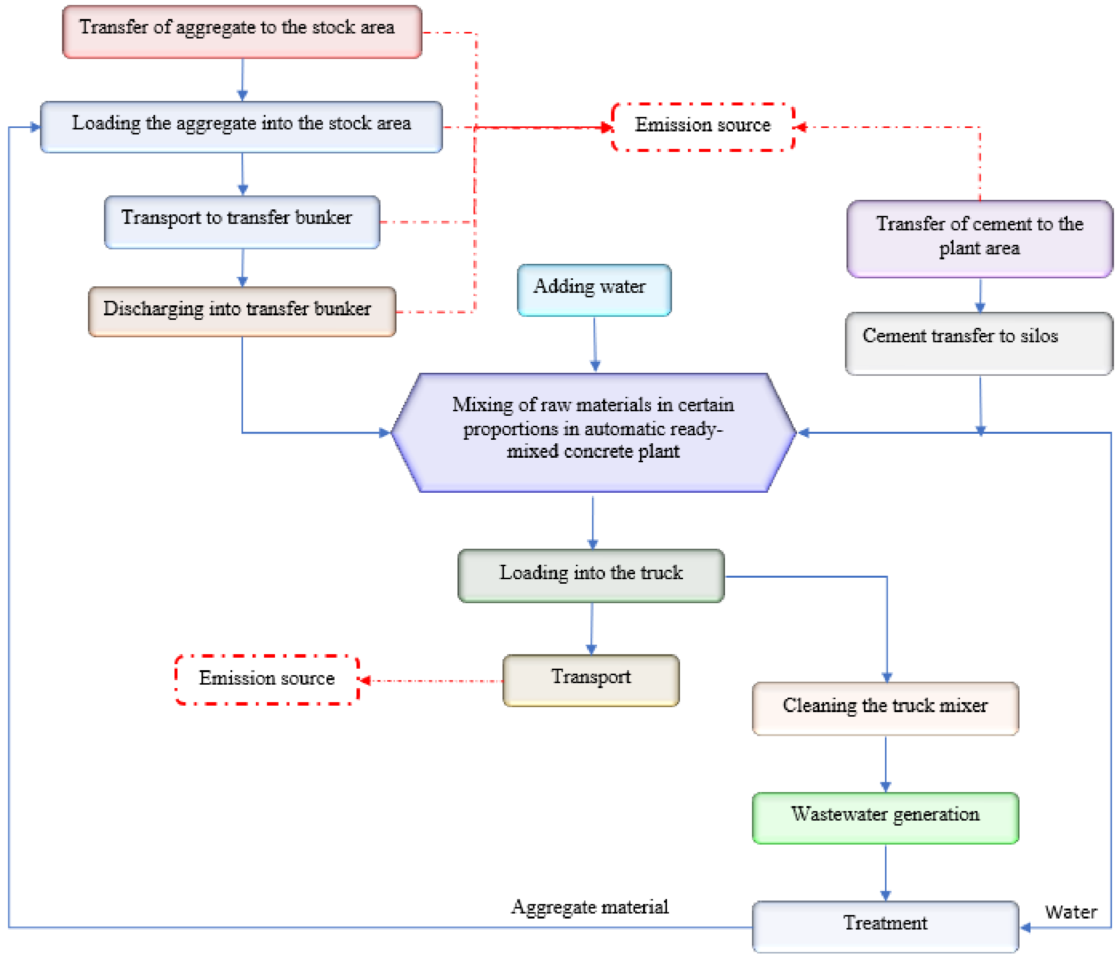

Figure 2. The flow chart of ready mix concrete production plant

The ready-mix concrete sector was first produced in Germany in the early 20th century (1903). In the thirties, ready-mix concrete production began in England and France, and in the forties in Spain and the Netherlands. After World War II, countries such as Belgium, Austria and Italy began production. In Turkey, the first ready-mix concrete production was made in Ankara in 1976 (Karakule and Akakın, 2005). Turkey has been the number one country in ready-mixed concrete production in Europe since 2009. Turkey produces more than twice as much concrete as the second country that produces the most concrete in Europe. Ready-mix concrete production quantities of different countries for 2022 are shown comparatively in Figure 3. As can be seen from Figure 3, Turkey is followed by Germany, France and Italy, respectively.

In 1988, ready-mixed concrete production in Turkey was 2 million m^3. In recent years, the demand for ready-mixed concrete has increased as a result of the increase in construction. The production of ready-mixed concrete reached 115 million m^3 in 2023 with rapid growth and increasing demand. While the amount of ready-mixed concrete produced per capita in Turkey was 1.08 m^3 in 2010, it increased to 1.35 m^3 in 2023. Annual production and per capita quantities of ready-mixed concrete in Turkey between 2010 and 2023 are shown in Figure 4.

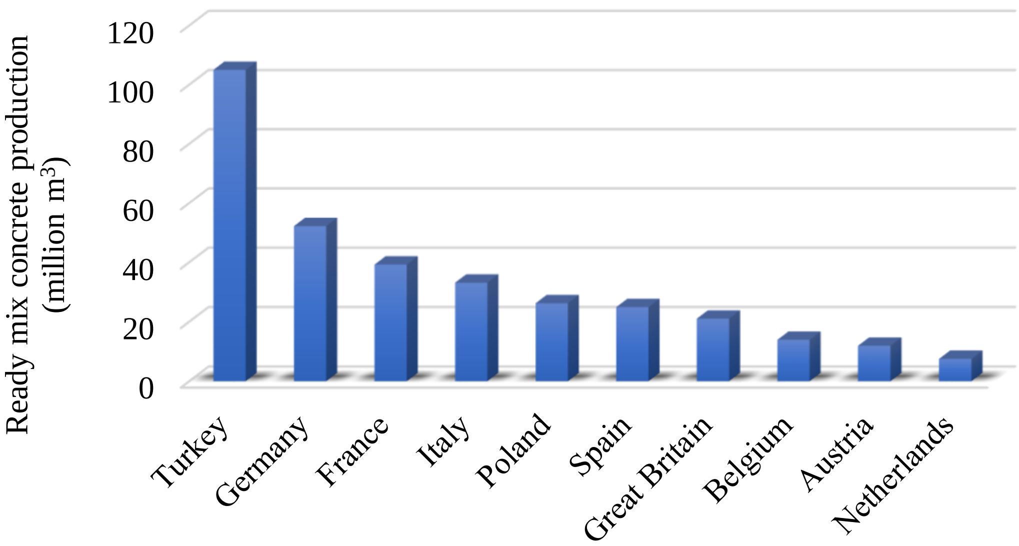

Figure 3. Ready-mix concrete production quantities of different countries in 2022 (URL-5)

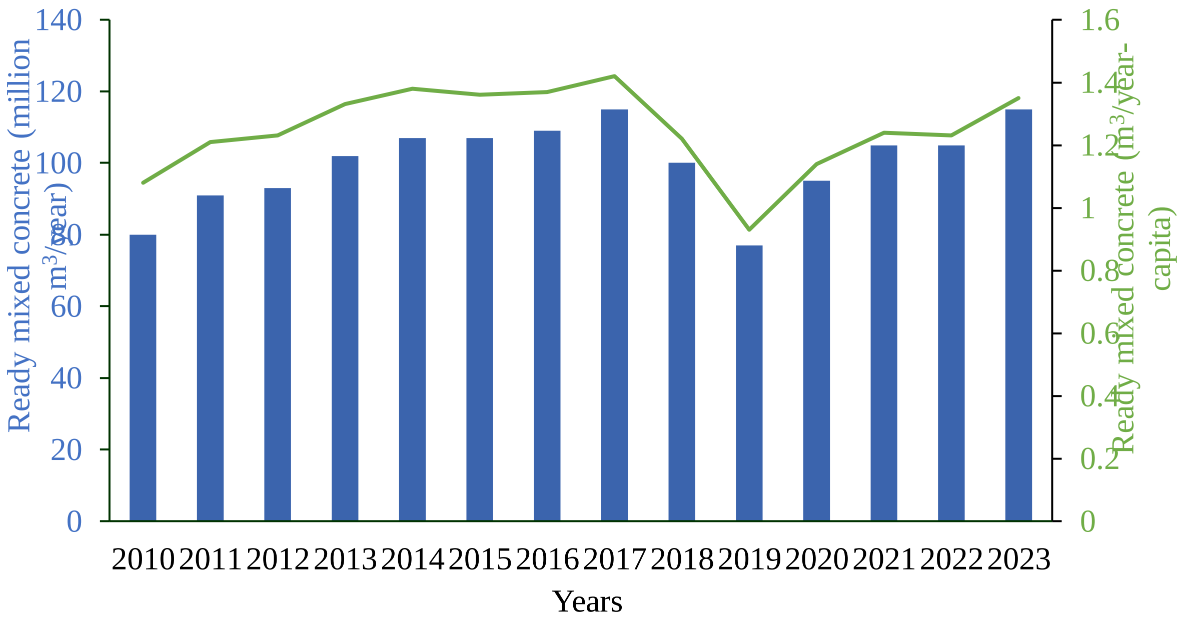

Figure 4. Changes in ready-mix concrete production quantities in Turkey (2010-2023) (URL-5)

Since 24% of natural resources are used for construction activities globally, the construction sector is a sector primarily responsible for resource consumption and waste generation (Miyan et al., 2024; Zabalza Bribián et al., 2011). Furthermore, emissions from the production and processing of raw materials used for the construction sector cause soil, water and air pollution, as well as many adverse effects on human and environmental health (Blankendaal et al., 2014; Tahir et al., 2022; Sbahieh et al., 2022). The construction sector is a primary contributor to greenhouse gas emissions (GHG), accounting for approximately 40–50% of global emissions (Khasreen et al., 2009). Although the contribution of concrete production to global emissions is around 8%, it reaches 86% when the energy needs of the equipment used in the production process are taken into account (Del Serrone and Moretti, 2023; Yan et al., 2010). Moreover, hazardous gases are formed during concrete production, which cause serious environmental effects (Terán-Cuadrado et al., 2024).

Cement as the main component in concrete production is an important source of carbon emissions that cause global warming. Cement, which is approximately 10% of the total concrete mass, serves as the basic binding agent used to bind sand and gravel in concrete production. Cement production in the world is quite high, approximately equal to the annual food production (Krausmann et al., 2018). Research is being conducted on the use of wastes such as fly ash, blast furnace slag, and marble mud as alternative binders in concrete production due to the negative environmental effects of cement (Colangelo et al., 2018; Arora et al., 2022; Tam, 2009; Colangelo et al., 2017; Messina and Colangelo, 2018).

During the production of ready-mixed concrete, wastewater is generated in many processes such as washing the truck mixer, concrete pump and other vehicles, cleaning the inside of the truck mixer chamber and the mixing mixer, rainwater flow from the ready-mixed concrete plant site, cleaning the ground of the plant, directing the incorrectly produced concrete to water pools. This wastewater, which is produced from washing the grounds and mixer trucks, has a high concentration of suspended solids, high turbidity, and high alkalinity among other parameters (Paula et al. 2016). If the wastewater generated in the production of ready-mixed concrete is discharged to the receiving environment instead of being evaluated in the form of recovery and reuse, it must comply with the discharge criteria of the Water Pollution Control Regulation.

A concrete recovery unit is used to separate wastewater, aggregate, and cement generated during the cleaning of the remaining concrete in transit mixers, concrete pumps, stationary mixers, and concrete carrier barrels and to recover these components (Coşkun, 2007). In the recycling system, first, fresh concrete's aggregate and cement grout are separated from each other. The aggregate is stored and used again in production. Cement grout, on the other hand, is processed in this pool if there is a separator pool in the system the sedimentation of fine material is prevented, and it is transferred back and directly to production. If there is no separator pool in the recycling unit, the cement grout separated from the aggregate is transferred to the sedimentation pools in the facility, and water and sludge are separated here; the obtained water is used again in production, while the sludge released is liquidated as waste (Nallı, 2006).

The solid waste generated in ready-mixed concrete plants is concrete mud and waste concrete. Solid waste disposal is the biggest problem experienced in ready-mixed concrete plants due to cost. Therefore, recycling systems should be established for the disposal of solid waste. Hazardous waste generated in ready-mixed concrete plants are generally oily cloth, hydraulic oils and contaminated waste. Waste oils generally occur in vehicle maintenance units. Moreover, exceptional situations such as a vehicle breaking down and leaking oil in the plant may also occur.

In ready-mixed concrete production facilities, noise is generated during the operation of the equipment and the loading of concrete into the vehicles. The facility should be set up, equipped, and operated in a way that prevents noise that may endanger environmental health and safety or create disturbances in the environment during production.

The efforts to reduce carbon emissions have begun within the framework of compliance with international steps taken within the scope of combating global warming in the industries. The emission sources need to be determined to know carbon emission values. Turkey is one of the leading countries with a ready-mixed concrete production capacity of 115 million m3 due to rapid growth and increasing demand. The amount of ready-mixed concrete produced per capita in Turkey grows yearly. Although there are studies on sectors such as textile, automotive, and metal processing in Turkey, there are limited studies that calculate carbon emissions by explaining all scopes and categories in the activities of a ready-mixed concrete production facility. The consumption of electrical energy, fuel, and water used in the production phase of ready-mixed concrete and concrete products and in the transfer of products is quite high compared to many industries. In this context, an important facility in Muğla province was examined. The greenhouse gases that may occur during the production process and the transfer of products and the carbon emissions of the facility were calculated. The facility activities were divided into scopes and categories according to GHG Protocol and ISO 14064-1:2018. Emission factors were determined according to DEFRA and IPCC and carbon emissions were calculated for all scopes and categories using the Tier 1 method. It is anticipated that the presented research article will be an important source for carbon footprint assessment for other industries in Turkey.

2. Materials and Methods

2.1. A facility of ready-mix concrete production and activity

In this study, the carbon footprint resulting from production activities in the ready-mixed concrete and concrete products production facility in Muğla province was calculated. The facility serves many official institutions regionally and more than 40 legal companies in the construction sector. The production area and vehicle park of the facility are shown in Figure 5.

Figure 5. The production area and vehicle park of the facility

The facility produces ready-mixed concrete, paving stones, concrete pipes of different sizes, sewer manholes, sewer manhole bases and asphalt. The facility's production capacity is 90 m^3/h, and it produces 384000 tons of ready-mixed concrete per year. The ready-mixed concrete requirement for the production of other products is approximately 238000 tons/year. Hot asphalt production capacity is 530400 tons/year. According to the facility capacity report, the annual consumption amounts of materials used in the production process are given in Table 1.

Table 1. Annual consumption capacity (main, auxiliary and packaging materials)

Type-charactеrıstıcs and technıcal name	Unit	Amount
Electric energy	Kwa	1957200
Fuel oil	Kg	1 30000
Oil	Liter	30600
Aggregate (gravel + sand)	Ton	796632
Cement	Ton	57600
Water	Ton	23040
Parquet paint	Ton	335
Bitumen	Ton	24398
Density enhancer	Ton	12730

2.2. The calculation of carbon emission

Carbon emissions were calculated by considering the emission sources in the facility for 2023. The factors that cause carbon emission formation in the facility were classified according to ISO 14064:2018 and GHG Protocol. IPCC Tier 1 methodology is the basic method, and it was used in the calculation. The Tier 1 method, the most widely used and simple methodological approach, combines activity data with coefficients that measure emissions per unit activity. The carbon equivalent amount is determined as a result of the Tier 1 calculation method. The tier 1 calculation method is given in Eq.1 (Garg et. al., 2006).

$$E = AD \ x \ EFxNCV \quad (1)$$

where E is the carbon equivalent amount of pollutants emitted into the atmosphere (tCO_2e); AD is the activity data (Tj, t, Nm); EF is the emission factor (t CO_2/Tj, t CO_2/t, t CO_2/Nm) and NCD is the Net Calorific Value (TJ/Gg).

IPCC and DEFRA national databases were used for emission factors to be used for carbon emission calculation and the Turkish Republic Ministry of Energy and Natural Resources Energy Efficiency and Environment Department Turkey National Electricity Grid Emission Factor was used for electricity emission factor data (URL-6). Three basic gases, CO_2, CH_4, and N_2O, can occur as a result of various activities. To calculate the results of all sources in tCO_2e in the carbon emission calculation, the global warming potentials depending on the heat retention capacities of the gases included in the IPCC Sixth Assessment Report were considered in the calculations.

3. Results and Discussion

Carbon emissions were calculated by considering the 2023 emission sources at the facility. The factors that cause carbon emissions at the facility are listed in Table 2. The emission factors to be used in the carbon emission calculation are listed in Table 3. The global warming potentials of the three basic gases (CO_2, CH_4, and N_2O) were used to calculate the results in tCO_2e in the carbon emission calculation. The potential of greenhouse gases on global warming for 100 years was adapted from the 6th Assessment Report of IPCC, and it was determined that the Global Warming Potential of CH_4 emissions is 27.9 times and N_2O emissions is 273 times that of CO_2 emissions.

Table 2. The distribution of activity data

Scopes	GHG Protocol	Category	ISO 14064-1:2018
Scope 1 Direct Emission	Fuel Consumption Natural gas consumption	Category 1	-
		Category 2	Electricity
Scope 2 Indirect Emission	Electricity	Category 3	Fuel Consumption
		Category 4	Water Consumption Waste Wastewater
Scope 3 Other Indirect Emission	Waste Wastewater Water Consumption	Category 5	-
		Category 6	-

Table 3. The emission factors to be used in the carbon emission calculation

Activity		Emission factor	Unit
Electricity Consumption		0.368	tCO_2/MWh (URL-6)
Fuel Consumption	CO_2	0.25070	$kgCO_2$/ kWh (URL-7)
	CH_4	0.00003	$kgCH_4$/ kWh (URL-7)
	N_2O	0.00330	kgN_2O/ kWh (URL-7)
Natural gas consumption	CO_2	0.20223	$kgCO_2$/ kWh (URL-7)
	CH_4	0.00031	$kgCH_4$/ kWh (URL-7)
	N_2O	0.00010	kg N_2O / kWh (URL-7)
Wastewater	CO_2	0.18574	$kgCO_2e$/ m^3 (URL-7)
Water Consumption	CO_2	0.15311	$kgCO_2$/ m^3 (URL-7)
Waste, Waste oil	CO_2	21.280	$kgCO_2$/ton (URL-7)
Waste, Paper cardboard	CO_2	6.41061	$kgCO_2$/ton (URL-7)

Table 4. The activity data of ready-mix concrete production facility in 2023

Activity data		Value	Unit
Total number of staff		40	person
Total working days		313	day
Total factory area		14596.9	m^2
Electricity Consumption	Machinery, equipment	480996	kWh
Fuel Consumption	Public transport	5240	liter
	Product transfer	385704	liter
Natural gas consumption	Production source	205136	m^3
Water consumption	Production source	23475	m^3
Wastewater	Personnel consumption	580	m^3
Waste	Waste oil	550	liter
	Paper cardboard	300	kg

The activity data of ready-mix concrete production facility in 2023 is given Table 4. The amount of electricity consumption due to the use of machinery, equipment and fittings in the facility in 2023 is 480996 kWh. In the calculation made using the Turkish National Electricity Grid emission factor of 0.368 tCO_2/MWh, the CO_2 emission value was determined as 177,007 tCO_2.

From Table 4, the operating staff is 40 people and transportation is carried out by public transportation. The fuel consumption was determined as 5240 L considering the transportation distance. Moreover, a fuel consumption of 385704 L is due to product shipment. The total fuel consumption of the business is 390944 L. Net calorific values of diesel and natural gas are taken from Annex-5 of the Rescript on Monitoring and Reporting of Greenhouse Gas Emissions. The Net Calorific Value used for diesel is 43 TJ/Gg. The fuel density value used for diesel is taken from the Official Statistics page of the Energy Market Regulatory Authority of the Republic of Turkey. The density value to be used is 0.833 kg/L. The tCO_2e values of three greenhouse gases, CH_4, N_2O, and CO_2, were calculated in fuel consumption. The emission from product transfer was found as 4422.5785 tCO_2e while the total CO_2 emission from public transport in 2023 was 60.0705 tCO_2e. Total emissions from fuel consumption were determined as 4482.649 tCO_2.

The net calorific value determined for natural gas is 48 TJ/Gg. Although the absolute density of natural gas varies depending on its composition, 0.78 kg/m³ was accepted. The tCO_2e values of three greenhouse gases, CH_4, N_2O, and CO_2, were calculated in natural gas consumption. The CO_2 emission value was calculated using the emission factors given in Table 3. The total CO_2 emission value from natural gas used by the facility in the production process was determined as 508.1128 tCO_2.

The facility uses a very high amount of water during the production phase. CO_2 emission values from water consumption were calculated for 2023 using an emission factor of 0.15311 $kgCO_2/m^3$. CO_2 emissions resulting from water consumption were calculated as 3.594 tCO_2. Water treatment conversion factors should be used for water returned to the sewage system through mains drains. Wastewater generation from personnel needs was 580 m^3. CO_2 emission from wastewater is calculated as 0.1077 tCO_2e using the emission factor value given in Table 3.

In the facility, the carbon emission value originating from waste generation for 2023 was calculated under two headings waste oil and paper-cardboard waste. Emission factors were 21.280 and 6.41061 $kgCO_2$/ton for waste oil and paper-cardboard waste, respectively. The CO_2 emission from waste oil generated during the production process was calculated as 0.0117 tCO_2 while this value for paper cardboard was 0.00192 tCO_2. The total CO_2 emission value from waste generation was determined to be 0.0136 tCO_2.

The total CO_2 emission value of this facility, which produces ready-mixed concrete and concrete products, is 5171.484 tCO_2 as a result of electricity, fuel, natural gas and water consumption, and wastewater and waste generation. When the activities of the facility in 2023 were evaluated, it was determined that the activity that had the most impact on the total CO_2 emission value was fuel consumption. Başoğul et al. (2021) evaluated the carbon footprint of a textile factory in Adıyaman province. The carbon footprint of the textile factory was determined by the Tier-1 method, considering the factors of service vehicle/diesel consumption, natural gas consumption, electricity consumption, and wastewater. The carbon footprint of the textile factory was calculated as 297.343 tCO_2/year, and it was emphasized that the most significant effect was caused by electricity consumption. The carbon footprint of a rubber manufacturing facility operating in Turkey with a production capacity of 17500 tons/year was determined using the IPCC's Tier-1 methodology. The annual total carbon footprint of the facility was estimated to be approximately 55000 tCO_2e (Mutlu et al., 2018).

4. Conclusions

The impact of the ready-mix concrete production sector on greenhouse gas emissions and climate change is often associated with its environmental effect. In this study, the CO_2 emission value created by a facility located in Muğla province that produces ready-mixed concrete and concrete products during production and transfer of products was investigated. As a result of electricity, fuel and water consumption, wastewater and waste generation, and natural gas use, the total CO_2 emission value of the facility was determined to be 5171.484 tCO_2. It was observed that fuel consumption is the activity that contributes the most to the facility's CO_2 emission value in 2023. Fuel consumption was followed by natural gas and electricity consumption, respectively. Although the facility has low emissions, it is very important to take the necessary precautions to minimize emissions in order to achieve the 2050 targets. The increasing and diversifying demands due to rapid population growth have led to developments in industrial production and technology. The intensive consumption of natural resources, the increasing energy demand, and the use of fossil fuels for energy supply have caused environmental problems such as climate change, desertification, and the decreasing of biological diversity. The need for concrete and the number of concrete production facilities are increasing accordingly with the rapid development of the construction sector in the world. As in all industrial production, processes in concrete production should be carried out in a way that will cause the least harm to the environment and should be managed in line with the sustainable environment principle.

Author's Contributions

Tuğçe Aydın Çora, Data curation, Investigation, Methodology, Writing-Original Draft.

Nurdan Gamze Turan, Conceptualization, Data curation, Investigation, Methodology, Project Administration, Resources, Supervision, Writing-Original Draft, Writing-Review & Editing.

Statement of Conflicts Interest

There is no conflict od interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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