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Estimating the contribution of transportation sector of greenhouse gases (GHG) emissions during the COVID-19 Pandemic Lockdown in Kuwait

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ABSTRACT

The transportation sector significantly contributes to greenhouse gas (GHG) emissions, primarily carbon dioxide (CO2), due to the combustion of fossil fuels. This study estimates the CO2 emissions from Kuwait's transportation sector during the COVID-19 pandemic lockdown. Utilizing data from the Kuwait National Petroleum Company (KNPC) and applying the Intergovernmental Panel on Climate Change (IPCC) guidelines, the study calculates CO2 emissions from gasoline and diesel consumption between 2015 and 2020. The results show a marked reduction in emissions during 2020 due to decreased vehicular activity amid the lockdown, highlighting the potential environmental benefits of reduced transportation activity. This research underscores the importance of sustainable transportation policies in mitigating environmental impacts.

INTRODUCTION

The transportation sector in all its forms, globally and locally, plays a crucial and vital role in the economic development of countries. This necessitates the availability of an integrated transportation system and an advanced network of roads and infrastructure. However, the transportation sector, particularly road transport, has significant negative impacts, especially in urban areas. Vehicles contribute substantially to environmental pollution through the emission of pollutants, including primary pollutants such as greenhouse gases, with carbon dioxide (CO2) being the most prominent, along with other gases like carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOC). These emissions also result in secondary pollutants such as ground-level ozone (O3), adversely affecting air quality (Almutairi and Koushki 2009; D`Angiola et al. 2010).

Over the past two decades, Kuwait has experienced significant urban and developmental growth across various economic sectors, including industry, transportation, and developmental and housing projects. This population and economic growth, coupled with a rise in individual income levels, has led to a substantial increase in the number of vehicles on the roads. This increase has been accompanied by a rise in traffic accidents and the resulting damages and injuries (General Traffic Department 2012), an increase in air pollutants emitted from vehicles, and the exacerbation of road congestion and time loss. A study by Schafer et al. (2009) indicates that urban residents spend a significant portion of their day commuting in vehicles, mostly in traffic jams caused by the annual increase in vehicle numbers. This also leads to higher emissions of air pollutants, which increase as speed decreases and traffic density rises (Heeb et al. 2008).

The environmental strategy of Kuwait highlights that the transportation sector is a key pillar of the country's economic development. However, alongside the industrial and energy generation sectors, it is also a major source of air pollution in the country (Environmental Public Authority 2002), posing risks to individual health, community safety, and sustainable development. Vehicles are among the largest consumers of fuel in the country, accounting for up to 19% of the total fuel consumed (MoO 2011), making them a significant source of greenhouse gas emissions in Kuwait. Recent studies on climate change have confirmed that the transportation sector contributes up to 26% of global carbon dioxide emissions (Chapman 2007), with this contribution rising to 80% in some urban areas (Almutairi and Koushki 2009). The International Energy Agency (IEA) reported that the transportation sector was responsible for 22% of global carbon dioxide emissions in 2008 (IEA 2010).

Despite the modernity of Kuwait's transportation sector, with its vehicles' compliance with stringent traffic laws and annual technical inspections to ensure efficiency and adherence to technical and environmental standards, the ease of vehicle ownership, subsidized fuel prices, easy acquisition of driving licenses, and inefficient public transport have exacerbated the problem of increasing vehicle numbers. This increase has not been accompanied by policy adjustments to curb the growth of vehicle numbers on urban roads. Therefore, it is imperative to assess the carbon dioxide emissions from the transportation sector in Kuwait and understand their environmental impact.

Problem Identification:
The population increase in Kuwait between 2015 and 2020, along with the expansion of developmental projects in the country, has led to a rise in the number of vehicles. The annual average growth rate of vehicles is approximately 6%, whereas the annual average growth rate of road lengths is around 2% (Central Statistical Bureau, 2011). This discrepancy exacerbates traffic congestion in urban areas, leading to increased air pollutant emissions, including greenhouse gases, and resulting in significant health, economic, and social impacts. Despite the measures taken by the Kuwaiti government, including the enactment of numerous laws and regulations to mitigate the rise in vehicle numbers, the problem persists and continues to worsen. This situation necessitates an environmental assessment.

Significance of the Study:
Kuwait places great importance on environmental aspects, continuously striving to preserve the environment and enhance human welfare. The importance of this research lies in addressing a critical issue—the increasing number of vehicles in Kuwait's urban areas and its environmental impact through harmful pollutant emissions, which threaten human life, health, and well-being, in addition to contributing to global climate change and the greenhouse effect. The COVID-19 pandemic introduced numerous health, economic, and environmental challenges worldwide, including in Kuwait, where health precautions to combat the pandemic affected economic activities, reducing greenhouse gas emissions, particularly carbon dioxide.

Human dependence on air is undeniable, requiring large quantities of it, with individuals inhaling approximately 15,000 liters of air daily. Thus, air pollution is one of the most dangerous types of pollution, leading to various diseases for those living in crowded cities or near industrial areas (Cunningham and Cunningham 2008; Brook 2008). Urbanization has globally increased pollution rates in urban areas, where population growth and human activities have led to a rise in vehicle ownership, a major source of air pollutants in urban areas (D`Angiola et al. 2010). Vehicle emissions from fuel combustion in internal combustion engines or fuel leaks during refueling contribute significantly to air pollution (Sperling and Gordon 2009).

The global reliance on vehicles has increased dramatically (IEA 2010). The number of vehicles, which was only 50 million in 1950, surpassed 600 million by 2010. Despite technological and technical improvements in vehicle engines, emissions from vehicles increased by approximately 47% from 1990 to 2008 due to the rise in vehicle numbers and the aging of existing vehicles. Air pollution is one of the most pressing environmental problems in urban areas and crowded cities in both developed and developing countries. Waked (2012) highlighted that vehicles significantly contribute to pollutant emissions in the Middle East. In the United States, vehicle growth rates have surpassed population growth rates (Sperling and Gordon 2009), with the population increasing by 50% from 1970 to 2008, while vehicle numbers rose by 150% during the same period, along with an increase in vehicle miles traveled, contributing to air pollution.

The U.S. Environmental Protection Agency (USEPA 2008) reported that transportation sector emissions accounted for 28% of the total carbon dioxide emissions in the United States. In Australia, the transport sector, particularly road transport, is a major contributor to pollution, with emissions increasing by about 30.6% from 1990 to 2005 (PTUA 2007). Studies indicate that 80% of carbon dioxide emissions in cities come from the transportation sector (Almutairi and Koushki 2009), which is responsible for 22% of global carbon dioxide emissions in 2008 (IEA 2010). This underscores the importance and necessity of curbing the continuous increase in vehicle numbers and evaluating transport policies to reduce fuel consumption and mitigate environmental impacts. Chapman (2007) noted that vehicles are the highest fuel consumers in the transport sector, which consumes 32% of the total global fuel, with 81% of this consumption attributed to road transport. The Economic and Social Commission for Western Asia (ESCWA 2005) indicated that the transport sector is a significant energy consumer in the Western Asia region, with consumption in 2003 estimated at 26.3% of total petroleum derivatives, rising to 36% in Saudi Arabia in 2005, the highest energy consumer in the Arab region, with a total of 25 million tons of fuel (ESCWA 2009). The industrial and transport sectors consume 80% of the total fuel in Saudi Arabia (PME 2005).

Air pollution increases with technological advancement and individual income levels, with the amount of pollutants emitted into the atmosphere depending on the economic activity level. The environmental Kuznets curve theory suggests that environmental indicators, such as air and water pollution, rise with increasing per capita income until a certain point. After

meeting basic needs, the desire for a pollution-free environment emerges, leading to increased emissions due to higher demand and consumption (Panayotou 2001; Hill 2004).

Vehicles are mobile sources of air pollution, emitting primary pollutants like carbon dioxide (CO2), hydrocarbons (HC), carbon monoxide (CO), sulfur dioxide (SO2), and nitrogen oxides (NOx) (Girard 2005), and secondary pollutants such as ground-level ozone (O3), sulfuric acid (H2SO4), and nitric acid (HNO3) (Uherek et al. 2010). Air pollutants are emitted from vehicles due to fuel combustion or evaporation. Gasoline is the most commonly used fuel in vehicles, and during fuel combustion to produce kinetic energy, the ideal reaction fully oxidizes the fuel in the internal combustion engine into water vapor and carbon dioxide (Hill 2004):

$$\text{Fuel} + O_2 \longrightarrow CO_2 + H_2O$$

Other pollutants result from incomplete oxidation reactions, such as carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM), or the oxidation of some gases, like nitrogen (N2), into nitrogen oxides (NOx), or sulfur (S) in some fuels and engine oils into sulfur dioxide (SO2). Additionally, vehicles emit various pollutants (depending on the vehicle's condition and type), including pollutants from the cooling system, tires, and brakes, which release heavy metals like lead, cadmium, arsenic, chromium, and nickel, posing serious health risks (Madani 1999; Kummer et al. 2009; Suzuki et al. 2009).

Fuel quality and type significantly influence pollutant concentrations from vehicles, as do the air-to-fuel ratio during combustion, ignition timing, internal combustion engine specifications and efficiency, and the presence of emission control devices like catalytic converters. For instance, vehicles with electronic fuel injection systems maintain an air-to-fuel ratio of 14.7:1.0, ensuring optimal fuel combustion. Catalytic converters reduce hydrocarbon and carbon monoxide emissions by 90% and nitrogen oxides by 70% compared to vehicles without catalytic converters (Faiz et al. 1996; Hits 2007).

The European Environment Agency (EEA 2008) emphasized that air pollutant exposure could harm health in both the short and long term, in addition to affecting natural ecosystems and contributing to building and material erosion. Fine particles emitted from vehicle exhausts can impact the lungs, heart, and circulatory system of all ages. Hassanien and Abdul-letif (2008) noted that polycyclic aromatic hydrocarbons are carcinogenic, with concentrations typically higher near congested roads. Traffic impacts air quality in urban areas and crowded cities, with Europe recording exceedances of annual guideline values for nitrogen dioxide (NO2) in 44% of urban air quality monitoring stations in 2010, posing health risks to residents (EEA 2012). A study on schools in California near highways (Singer et al. 2004) found the highest nitrogen dioxide concentrations in schools close to highways and in the direction of prevailing winds.

The World Health Organization (WHO 2005) stated that air pollution is a major problem in both developed and developing countries, causing millions of deaths and illnesses due to respiratory diseases, asthma, cardiovascular diseases, and lung cancer, particularly among those living near busy streets in urban areas. Recent research indicates that the annual cost of air quality degradation is significant, reaching about 2% of GDP in developed countries and over 5% in developing countries, including costs from deaths, chronic diseases, hospital treatments, and reduced productivity (Arab Forum for Environment and Development 2008). The World Resources Institute (WRI 2007) estimated the economic losses from unsustainable transport, noting that congestion costs exceed 3% of GDP in many countries.

In Kuwait, the study by Dasouki et al. (1987) was among the first to indicate that air pollution in residential areas is due to increasing traffic, showing a strong correlation between average concentrations of some pollutants from vehicle exhausts, such as hydrocarbons (HC) and carbon monoxide (CO), and vehicle numbers. The study found that hydrocarbon concentrations exceeded permissible levels in some residential areas in Kuwait. Jallad and Jallad (2012) noted that the annual vehicle growth rate in Kuwait ranged between 6-9%, potentially worsening air pollution. Abdul Wahab (2009) indicated that hydrocarbon and nitrogen dioxide concentrations in the Khaldiya area exceeded residential air quality standards during peak traffic times.

Studies on the Transport Sector as a Source of Greenhouse Gas Emissions

The phenomenon of global warming is defined as the gradual increase in the temperature of the Earth's surface layer of the atmosphere due to the emission of greenhouse gases (GHGs) (Hites, 2007; IPCC, 2007). Studies indicate that the global climate is changing, with effects currently emerging due to the accumulation of GHGs in the atmosphere from human activities, such as changes in seasonal timings, average temperature shifts, and increased extreme weather events, among others. These impacts are expected to worsen in the future (UNDP, 2008), exposing millions of people, especially in developing countries, to food and water resource shortages, rising sea levels, and increased health risks.

Climate change represents one of the most severe environmental risks facing the world today. Extreme weather conditions over the past few years globally, including the Gulf region's extreme temperatures, hurricanes, floods, and other events, highlight the impact of this phenomenon on the region (UNEP, 2010; AFED, 2011). A study by Nasrallah et al. (2004) indicated that the intensity and duration of heat waves in Kuwait have increased over the past decade.

Globally, temperatures have risen by approximately 0.6 degrees Celsius over the past century. The 1990s included seven of the warmest years on record, with 1998 being the hottest year in 140 years (UNEP-GEO 4, 2007). Scientists have warned that temperatures could rise by 1 to 2 degrees Celsius by 2020 and by 2 to 5 degrees Celsius by 2070, according to the Intergovernmental Panel on Climate Change (IPCC, 2007). Scientific evidence suggests that human activities are the primary causes of GHG emissions leading to global warming and climate change, which could result in catastrophic damage in some areas. Industrial and technological advancements since the last century have led to significant industrial and commercial growth, accompanied by substantial natural resource consumption, particularly energy, and increased pollutant emissions and waste production. This has resulted in numerous environmental problems, notably climate change, ecological imbalance, natural resource depletion, and ecosystem degradation, threatening human life and well-being (Vallero, 2008; Sperling and Gordon, 2009; UNEP-GEO, 2012).

Vehicles are mobile sources of pollution and a significant source of GHGs such as carbon dioxide and nitrous oxide (IPCC, 2006). The increased reliance on private vehicles has led to higher GHG emissions in urban areas, where vehicles are now the primary source of these gases. There are over 1.2 billion vehicles worldwide, most of which are in developing countries (UNHSP, 2011). The transport sector in Arab countries is a significant energy consumer with low efficiency, consuming 32% of total energy consumption and emitting 22% of total GHG emissions (AFED, 2009; ESCWA, 2009).

Climate change studies indicate that the transport sector contributes to GHG emissions, with emissions increasing by 28% from 1990 to 2005 in the European Union, while other sectors saw a 3% reduction in emissions (EEA, 2009). This increase occurred despite improvements in engine efficiency and fuel quality, suggesting that the rise in transportation is the cause. Chapman (2007) noted that the transport sector is one of the few sectors with annually increasing emissions, responsible for 26% of global carbon dioxide emissions.

The International Energy Agency (IEA, 2011) highlighted that the transport sector significantly contributes to GHG emissions in Canada, accounting for about 25% of total emissions in 2009, a 20% increase from 1990. In the United States, GHG emissions from the transport sector constitute approximately 27% of total emissions (USEPA, 2006). The European Environment Agency (EEA, 2012) reported that GHG emissions from the transport sector in Europe increased by 26% in 2010 compared to 1990.

A World Bank study on the transport sector in Asian countries from 1980 to 2005 indicated that the transport sector's contribution to carbon dioxide emissions in Vietnam increased from 14% to 24%, with 92% of these emissions from road transport. Economic growth, population increase, and higher energy consumption in the transport sector were the main drivers of these emissions (Timilsina and Shrestha, 2009).

A study by Uherek et al. (2010) showed that emissions from the road transport sector affect air quality and climate change, with pollutants rapidly increasing in developing countries. There is a close relationship between the environment and economic development, where economic growth that disregards the ecological capacity and environmental efficiency leads to deterioration, resulting in an inability of the environment to rectify the imbalance, exacerbating the problem and affecting future generations (UNEP, 2010).

Research Methodology

The estimation of carbon dioxide (CO2) emissions, a significant greenhouse gas, from the transport sector in Kuwait involves the application of the Intergovernmental Panel on Climate Change (IPCC, 2006) guidelines and equations. This methodology uses data on the country's energy supply for the transport sector and calculates CO2 emissions from fuel combustion based on default emission factors for the types of fuel used in the transport sector (Table 1). The calculation process involves the following steps:

1. **Converting the Unit of Fuel Quantity:** Convert the quantity of fuel consumed from liters to barrels by dividing by 159 (1 barrel = 159 liters).
2. **Converting Barrels to Tonnes Equivalent:** Convert barrels to tonnes equivalent, considering the density of gasoline and diesel (1 tonne of diesel = 7.46 barrels, 1 tonne of gasoline = 8.53 barrels).

3. **Converting Tonnes Equivalent to Energy Units:** Convert the tonnes equivalent to energy units using the Net Calorific Value (NCV) for use in the IPCC (2006) equation (diesel: 43 terajoules per 1000 tonnes, gasoline: 44.3 terajoules per 1000 tonnes).
4. **Calculating CO2 Emissions:** Calculate the CO2 emissions for each type of fuel by applying the equation and using the default emission factors for the fuel (Table 1) as suggested by the IPCC:

Emissions = ∑ [Fuel a X EFa]

Where:

- Emissions = total CO2 emissions (in kilograms)
- Fuel_a = amount of energy from fuel sold to vehicle fueling stations (in terajoules)
- EF_a = emission factor for the fuel type (kg/terajoule)
- a = type of fuel (gasoline, diesel, or gas)

Table 1: Default Emission Factors for CO2 from Fuel Used in the Road Transport Sector (IPCC, 2006).

Fuel Type	Emission Factor
Gasoline	69,300
Diesel	74,100

Contribution of Vehicles to Greenhouse Gas (CO2) Emissions in Kuwait

Vehicle Usage and Fuel Consumption Statistics

The number of vehicles in Kuwait has steadily increased from 1,925,168 in 2015 to 2,295,606 in 2020, while road lengths have also expanded from 7,518 km to 8,288 km. Fuel consumption data indicates varying trends for gasoline and diesel over the years Table 2 and Figure 1.

Table 2: Vehicle Usage and Fuel Consumption

Year	Road Lengths (km)	Number of Vehicles	Gasoline Consumption (Million Liters)	Diesel Consumption (Million Liters)
2015	7518	1925168	4150.0	1761.9
2016	7620	2001940	4150.0	1823.0
2017	7757	2079516	4362.3	2038.1
2018	7994	2075475	4499.8	2183.0
2019	8180	2236311	4484.0	2269.3
2020	8288	2295606	3534.6	1915.7

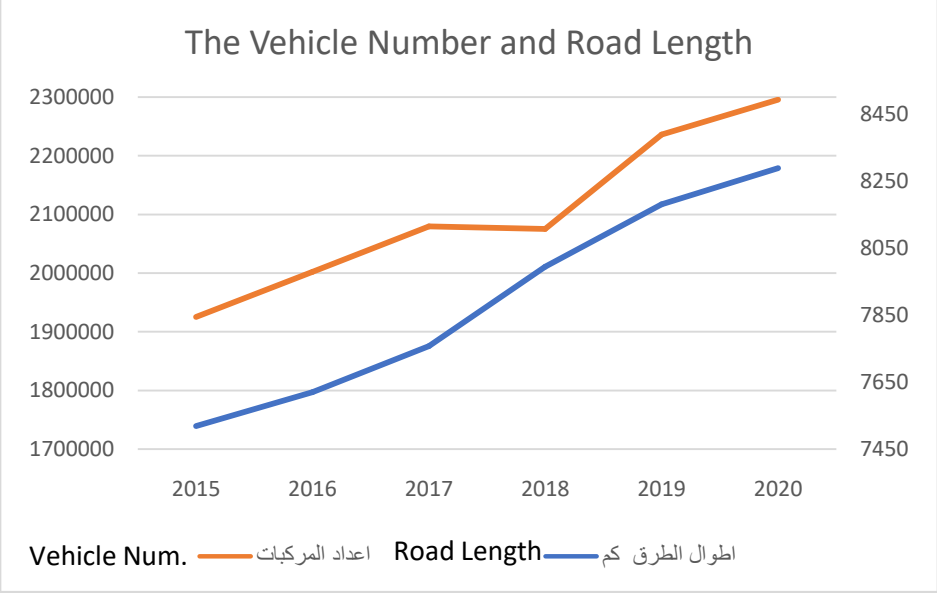

Figure 1: Vehicle Usage and Fuel Consumption

The CO2 emissions from the vehicle sector in Kuwait for the period 2015-2020 were estimated by collecting data on fuel consumption for the transport sector from the Kuwait National Petroleum Company (KNPC) statistics on the amount of gasoline and diesel sold and consumed locally. The data were calculated based on the fiscal year starting in April and ending in March of the following year. The annual increase in fuel consumption over the study period reflects the annual growth in the number of vehicles and their usage. However, a significant reduction in fuel consumption was observed in 2020 due to the complete lockdown, cessation of traffic, and the adoption of remote work and education (Figure 2).

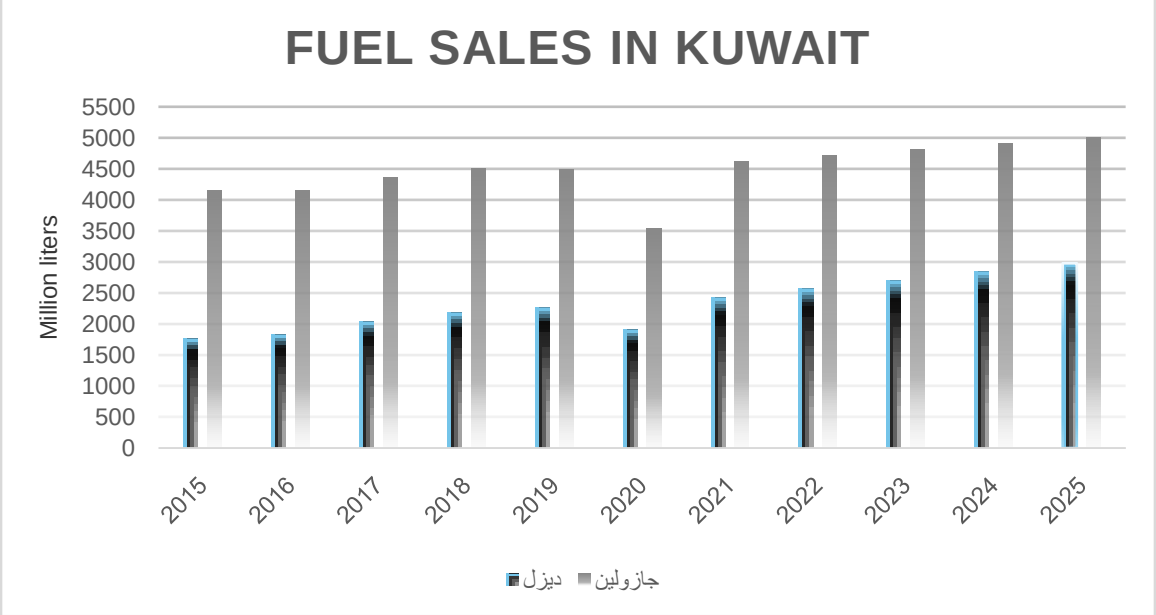

Figure 2: Fuel Sales in Kuwait from 2015 to 2020 (KNPC, 2021)

Diesel (black) Gasoline (gray)

The amount of carbon dioxide (CO2) emissions from the use of sold fuel (gasoline and diesel) was calculated using the following equation, as adopted by the Intergovernmental Panel on Climate Change (IPCC, 2006):

Emissions = ∑ (Fuel (a) X EFa)

Where:

- **Emissions** = CO2 emissions (measured in kilograms).
- **Fuela_aa** = Amount of energy produced from the fuel sold to vehicle fueling stations (in terajoules).
- **a** = Type of fuel consumed (gasoline or diesel).
- **EFa_aa** = Emission factor for the fuel consumed (kg/terajoule) (Table 3).

Table 3 shows the amount of CO2 emissions during the period from 2015 to 2020 resulting from the use of gasoline and diesel sold in the local market and consumed in Kuwait.

Table 3: Calculated CO2 Emissions During the Study Period 2015-2020

Emissions	Consumption	Gasoline	Emissions	Consumption	Diesel
Thousand Tons	**Tonnes Equivalent**	**Year**	**Thousand Tons**	**Tonnes Equivalent**	**Year**
11223.38	3655835	2015	4903.86	1539046	2015
11128.98	3625087	2016	5073.92	1592418	2016
11698.3	3810535	2017	5672.6	1780311	2017

12067.03	3930643	2018	6075.9	1906883	2018
12024.66	3916841	2019	6316.1	1982268	2019
9478.675	3087526	2020	5331.93	1673393	2020

Figure 3 illustrates that CO2 emissions have been increasing over time due to the rising energy consumption in the vehicle transport sector until 2020, when a decline was observed compared to previous years. The emissions resulting from gasoline consumption are higher than those from diesel fuel consumption, despite the higher emission factor of diesel fuel compared to gasoline. This is because the majority of vehicles in Kuwait use gasoline, while diesel is predominantly used by heavy transport vehicles.

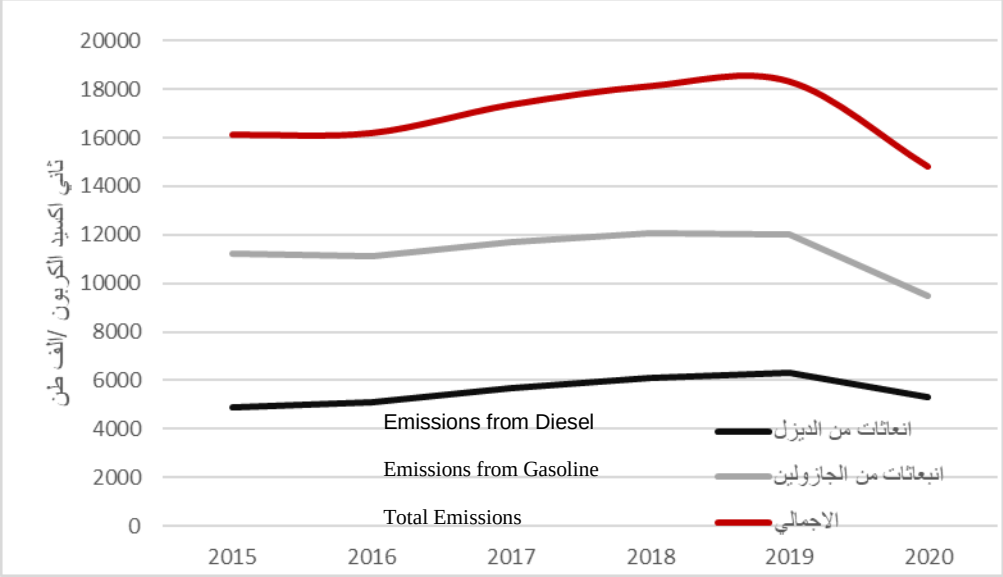

Figure 3: CO2 Emissions from Fuel Consumption in the Transport Sector in Kuwait (2015-2020)

Figure 3 shows that CO2 emissions have generally increased over time due to the rising energy consumption in the vehicle transport sector, reaching a peak before declining in 2020. The emissions from gasoline consumption are higher than those from diesel, despite the higher emission factor for diesel. This is because the majority of vehicles in Kuwait use gasoline, with diesel being primarily used by heavy transport vehicles.

According to the calculations by the International Energy Agency (IEA, 2011), the CO2 emissions from the road transport sector in Kuwait were 11.6 million tons in 2009. However, according to this study, these emissions reached 18.3 million tons in 2019, then decreased to 14.81 million tons in 2020 during the COVID-19 pandemic. This reduction was due to the cessation and decrease of traffic, along with remote work and education, which led to reduced fuel consumption and consequently lower emissions during that period.

RESULTS AND DISCUSSION

The results indicate a significant impact of the COVID-19 pandemic lockdown on CO2 emissions from Kuwait's transportation sector. From 2015 to 2019, there was a consistent increase in CO2 emissions, peaking at 18.34 million tons in 2019. This increase correlates with rising fuel consumption driven by economic growth and an increase in the number of vehicles on the roads.

However, in 2020, there was a notable decrease in emissions, with total CO2 emissions dropping to 14.81 million tons. This reduction is primarily attributed to the pandemic lockdown, which led to a significant reduction in vehicular movement due to restrictions on travel, the shift to remote work, and the closure of many businesses. The decrease in fuel consumption during this period is evident from the KNPC data, which shows a decline in both gasoline and diesel sales.

The emissions from gasoline were consistently higher than those from diesel throughout the study period, despite the higher emission factor for diesel. This is because gasoline-powered vehicles dominate Kuwait's transportation sector, while diesel is mainly used by heavy transport vehicles. The higher prevalence of gasoline vehicles results in greater overall CO2 emissions from gasoline compared to diesel.

These findings align with global observations during the pandemic, where reduced transportation activity led to significant decreases in air pollution and GHG emissions. The temporary nature of these reductions highlights the need for long-term sustainable transportation policies. Possible measures include promoting the use of public transportation, encouraging the adoption of electric vehicles, and implementing stricter fuel efficiency standards to reduce the environmental impact of the transportation sector.

CONCLUSION

This study provides a detailed assessment of CO2 emissions from Kuwait's transportation sector during the COVID-19 pandemic lockdown. The findings demonstrate that reduced vehicular activity can significantly lower GHG emissions, illustrating the potential environmental benefits of sustainable transportation policies. From 2015 to 2019, there was a consistent increase in CO2 emissions, peaking at 18.34 million tons in 2019. This rise correlates with economic growth and the increasing number of vehicles on the roads.

However, in 2020, a notable decrease in emissions was observed, with total CO2 emissions dropping to 14.81 million tons. This reduction is primarily attributed to the pandemic lockdown, which led to a significant reduction in vehicular movement due to restrictions on travel, the shift to remote work, and the closure of many businesses. The decrease in fuel consumption during this period is evident from the KNPC data, which shows a decline in both gasoline and diesel sales.

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In conclusion, the study underscores the importance of sustainable transportation policies in mitigating environmental impacts. The observed decrease in emissions during 2020 serves as a compelling case for policymakers to consider long-term strategies to manage transportation emissions. Future research should focus on evaluating the effectiveness of different policy measures and exploring innovative solutions to reduce transportation-related emissions in Kuwait and similar urban settings.

REFERENCES

[1]. **Abdul-Wahab, S. (2009).** Two case studies of air pollution from Oman and Kuwait. *International Journal of Environmental Studies*. 66 : 179 -191.

[2]. **Abdul-Wahab, S. and Bouhamra, W. (2004).** Diurnal variation of air pollution from motor vehicles in residential area .Intern. J. *Environ. Studies*. 61 : 73-98.

[3]. **AFED (2009).** Arab Environment : Climate Change - Impact of Climate Change on Arab Countries. Arab Forum for Environment and Development (AFED), Beirut. 159 p.

[4]. **Albassam, E., Khan, A. and Popov,V. (2008).** Management of Air Quality in the Vicinity Congested Area in Kuwait. *Environmental Monitoring and Assessment*, pp 554-559.

[5]. **Almutairi, N. , Al-Attar M.,and Al-Rukaibi, F. (2011)** Traffic-generated noise pollution: exposure of road users and populations in Metropolitan Kuwait. *Environ Monit Assess*. 183 : 65–75.

[6]. **Almutairi, N.,and Koushki,P.(2009).** Potential Contribution of Traffic to Air Pollution in The State of Kuwait, *American journal of Environmental Sciences*. 5 : 218-222.

[7]. **Chang, S., and Lee, C.(2008).** Evaluation of the temporal variations of air quality in Taipei City, Taiwan, from 1994 to 2003. *Journal of Environmental Management*. 86: 627–35.

[8]. **Chapman, L.(2007).** Transport and Climate Change : a review, *Journal of Transport Geography*, Elsevier. 15 : 354-367.
[9]. **D`Angiola, A., Dawidowski, L., Gomez, D., Osses, M. (2010).** On-road traffic emissions in megacity, *Atmos. Environment*.44 : 483-493.
[10]. **EEA (2008).** Transport remains main source of health-damaging pollutants. http://www.eea.europa.eu/highlights/air-pollution-remains-a-threat-to-health-in-eu-27.
[11]. **EEA (2012).** The contribution of transport to air quality. EEA Report No 10/2012. European Environment Agency. 83 p.
[12]. **Elkarim, M., Khogali, M. and Zeglam, H. (2005).** Traffic air pollution in Kuwait : preliminary results for nitrogen oxides and carbon monoxide, University of Kuwait.
[13]. **Elmi, A. and Al Rifai, N. (2012).** Pollutant emissions from passenger cars in traffic congestion situation in the state of Kuwait: option and challenges. *Clean Techn Environ Policy*. 14 : 619-624.
[14]. **ESCWA. (2009).** Transport for Sustainable Development in The Arab Region: Measures, Progress Achieved, Challenges and Policy Frame Work, Economic and Social Commission For Western Asia. 37 p.
[15]. **Fyhri, A. and Aasvang, G.(2010).** Noise, sleep and poor health: Modeling the relationship between road traffic noise and cardiovascular problems. *Science of the Total Environment*. 408: 4935-4942.
[16]. **Hester, R. and Harrison, R. (2004).** Transport and The Environment, The Royal Society Of Chemistry, UK. 164 p.
[17]. **Hill, M.(2004).**Understanding Environmental Pollution. Cambridge University Press, UK. 486p.
[18]. **Hites, R.(2007).** Elements of Environmental chemistry. John Wiley. USA. 204 P.
[19]. **IEA (2011).** CO2 emissions from fuel combustion highlghts. International Energy Agency, Report. 124 p.
[20]. **IEA (2010).** CO2 emissions from fuel combustion highlghts. International Energy Agency, Report. 130 p.
[21]. **IPCC (2007**). Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.Cambridge UniversityPress, Cambridge, UK http://www.ipcc.ch/ipccreports/ar4-wg3.htm.
[22]. **Jallad, K., and Jallad, C.,(2012).** Characterization of Road Traffic Emissions in a Densely Populated Residential Area of Kuwait, *Environment and Natural Resources Research*. 2 : 2-16.
[23]. State of Kuwait Initial National **KEPA (2012)** Communication (INC) under the United Nations Framework Convention on Climate Change (UNFCCC), Kuwait Environment Public Authority. 90 p.
[24]. http://unfcc.int/resource/doc/natc/Kwtnc1.pdf
[25]. **Kristensen, P. (2004).** The DPSIR Framework. Paper presented at the 27-29 September 2004 workshop, Nairobi, Kenya
[26]. **Kummer, U., Pacyna, J., Pacyna, E. and Friedrich, R. (2009)**. Assessment of heavy metal releases from the use phase of road transport in Europe. *Atmospheric Environment*. 43 : 640-647.
[27]. **).** Annual Report, Ministry Of Oil www.moo.gov.kw **19 MoO (20**
[28]. **MoPW (2010).** Traffic Impact Study. Ministry of Public Works-Road Administration. 114 P.
[29]. **PME (2005).** First National Communication of the Kingdom of Saudi Arabia. Presidency of Mtereorology and Environment. 142 p.
[30]. **Sperling, D. and Gordon, D.(2009).** Tow Billion Cars Driving Toward Sustainability. Oxford University Press, New York, 304 p.
[31]. **UNEP.(2005).** Global strategy for lower sulphur fuels of the partnership for clean fuels and vehicles. Nairobi, Kenya: Clearing-house for the partnership for clean fuels and vehicles. United Nations Environmental Programme. Retrieved from http://www.unep.org/transport/pcfv/PDF/PCFVSulphurStrategy- March08.pdf
[32]. **UNEP (2012).** Global Environment Outlook5 (GEO 5). 551p
[33]. http://www.unep.org/geo/pdfs/geo5/GEO5_report_full_en.pdf
[34]. **UNEP (2007).** Global Environment Outlook4 (GEO 4). 572p
[35]. www.unep.org/geo/geo4 report_full_en.pdf
[36]. **United Nations Development Programme and General Directorate of Traffic. (2009).** National traffic and transport sector strategy for Kuwait 2009-2019. UNDP and General Directorate of Traffic Project 2009-2013 Report. 55p
[37]. **Waked, A.(2012).** Emissions of air pollutats from road transport in Lebanon and other countries in the Middle East region, *Atmospheric Environment*. 61: 446-452
[38]. **WHO (2005)** Health Effects of Transport-Related air Pollution. World Health Organization. 205p.
[39]. **WRI (2007).** "Sustainable Transport in the Developing World." World Resources Institute. http://earthtrends.wri.org/updates/ node/135 [accessed June 17, 2012].

Arabic References:

[1]. Central Statistical Bureau (2019). Annual Statistical Abstract, Issue 55, Kuwait.
[2]. General Traffic Department (2012). Retrieved from http://www.moi.gov.kw/gdt (Accessed on 29 Nov 2012).

[3]. ESCWA (2005). Improving Energy Efficiency and Cleaner Fossil Fuel Use in Selected Sectors in Some ESCWA Countries. Economic and Social Commission for Western Asia, United Nations. 76 pages.
[4]. General Secretariat of the Cooperation Council for the Arab States of the Gulf (2008). Executive Regulations for Ambient Air Quality Standards, Noise Level Standards, and Wastewater Regulations. Cooperation Council for the Arab States of the Gulf.
[5]. Al-Senhoury, Ibrahim, and Al-Nashmi, Mohammed (1996). Air Quality in Riyadh City and Evaluation of Alternatives to Reduce Emissions from Transportation. The High Commission for the Development of Riyadh, 17 pages.
[6]. Economic and Social Commission for Western Asia (ESCWA) (2005). Improving Energy Efficiency and Cleaner Fossil Fuel Use in Selected Sectors in Some ESCWA Countries. 76 pages.
[7]. Arab Forum for Environment and Development (2011). Green Economy in a Changing Arab World. Annual Report of the Arab Forum for Environment and Development, Beirut, 322 pages.
[8]. Arab Forum for Environment and Development (2008). Arab Environment: Future Challenges. Report of the Arab Forum for Environment and Development, Beirut, 285 pages.
[9]. Environmental Public Authority (2013). www.beatona.org.kw (Accessed on 29 Feb 2013).
[10]. Environmental Public Authority (2002). Environmental Strategy for the State of Kuwait. Part One, Kuwait, 682 pages.
[11]. Intergovernmental Panel on Climate Change (IPCC) (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Institute for Global Environmental Strategies (IGES), Japan, 78 pages. Retrieved from www.ipccnggip.iges.or.jp/public/2006gl/index.html.
[12]. United Nations Development Programme (UNDP) (2008). Adaptation to Climate Change: The New Development Challenge for the Developing World. United Nations Development Programme, 36 pages.
[13]. United Nations Environment Programme (UNEP) (2010). Environmental Outlook for the Arab Region: Environment for Development and Human Well-being. Division of Early Warning and Assessment (DEWA), 441 pages.
[14]. Kuwait Municipality (2004). Development and Modernization of the Third Structural Plan for the State of Kuwait, Working Paper No. 19: Land Use and Activities. Kuwait Municipality, 134 pages.
[15]. Abdel Maqsoud, Zain El-Din (2000). Contemporary Environmental Issues. Third Edition, Manshaat Al-Maaref, Alexandria, 361 pages.