Evaluation of Industrial CO_2 Emissions from Cement Production and Transportation Sector in Iraq Using IPCC Methods

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Abstract

Cement production (CP) and transportation sector are main sources of increasing CO_2 in the atmosphere, which had major responsible for climate changes. These two sectors (CP and transportation) have high percentage of globally CO_2 emissions by burn fossil fuel, especially in Iraq, so that this research focuses on this issue. Intergovernmental Panel on Climate Changes (IPCC) carried out 2006 guidelines, which include formulas and equations to calculate CO_2 emissions and other greenhouse gases. The results shown there are multi fluctuations of CP during study period 1970-2013, which reflected on the CO_2 emissions that released from it. The CP has highest value 12000 kilo ton (kt) in 2013. CO_2 emissions have the highest value 4680 Giga gram (Gg) in 2013. The percentage of share of CO_2 emissions from CP increased from 1 % in 1970 to 4 % in 2013. CO_2 emissions due to transportation have grown significantly from 2200 Gg in 1970 to 39000 Gg in 2013, because of increase in the number of different modes of transportation and consumption large quantities of fuel. The percentage of share of CO_2 emissions from transportation in Iraq increased from 10 % in 1970 to 30 % in 2013.

Key words: Industrial CO_2 Emissions, Cement Production, Transportation Sector, IPCC.

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تقدير انبعاثات ثاني اوكسيد الكربون الصناعية من انتاج السمنت وقطاع النقل IPCC في العراق باستخدام طرائق

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الخلاصة

ان انتاج السمنت وقطاع النقل من المصادر المهمة لزيادة غاز ثاني اوكسيد الكربون (CO_2) في الغلاف الجوي، الذي يعد المسؤول الرئيسي للتغيرات المناخية. ان قطاعي انتاج السمنت والنقل لهما نسبة عالية عالميا لانبعاثات CO_2 نتيجة احتراق الوقود الاحفوري خاصة في العراق ، لذلك يركز هذا البحث على هذه المسألة. ان الهيئة الحكومية المعنية بالتغيرات المناخية (IPCC) اقرت الخطوط التوجيهية لعام 2006 التي تتضمن صيغ ومعادلات لحساب انبعاثات CO_2 وغازات الدفيئة الاخرى. اظهرت النتائج وجود تقلبات عديدة في انتاج السمنت خلال فترة الدراسة (1970-2013) والذي انعكس بدوره على انبعاثات CO_2 المنطلقة منه. وصل انتاج السمنت اعلى قيمة 12000 كيلو طن عام 2013. بلغت انبعاثات CO_2 قيمتها الاعلى 4680 كيلو طن عام 2013. ان النسبة المئوية لحصة انبعاثات CO_2 من انتاج السمنت في العراق ازدادت من1%عام 1970 الى4% في عام 2013. ازدادت انبعاثات CO_2 من قطاع النقل من 2200 غيغا غرام عام 1970 الى 9000 غيغا غرام في 2013 بسبب زيادة اعداد وسائط النقل واستهلاك كميات كبيرة من الوقود. ان النسبة المئوية لحصة انبعاثاتCO_2 من قطاع النقل في العراق ازدادت من10%عام 1970 الى30% في عام 2013 .

الكلمات المفتاحية : انبعاثات ثاني اوكسيد الكربون الصناعية، انتاج السمنت، قطاع النقل ، IPCC.

Introduction

Carbon dioxide (CO_2) is one of greenhouse gasses (GHGs), which results by combustion of fossil fuels. The major increase in the atmospheric CO_2 started in the 1850 has reached to amount (400 part per million (ppm)) in 2012 and go on growth rate by slope about (1.5 ppm/ year). This rate has rise to about (30%) from 1850 to 2012 [1]. Some of stationary emissions sources include cement production (CP), while transportation is mobile emissions source that include (road transport, civil aviation, navigation, and railways). Two activities represent key categories and important source to CO_2 emissions [2]. There are many studies

deals with evaluating of CO_2 emissions due to CP and transportation sector. Hoveidi et al, (2013) [3] studied appropriate measures to reduce CO_2 emissions from Iran's cement industry. There are (54) active cement factories in Iran. Results show that the amount of CO_2 released in cement production (calcination), Is much more than its amount released due to consumption of energy in thermal and electric forms. Young Crane Consulting Co. Ltd. (YCC), (2011) [4] selected (17) cities in China and (6) transport modes (buses, metro, private cars, taxies, trams and trucks) in 2011 to estimate CO_2 emissions. Total CO_2 emissions from transport modes for the (17) cities as a whole have increased from about (62 million tonne (Mt)) in 2005 to (123 Mt) in 2009, which had an average annual growth rate of about (19%). These studies and others confirm that cement industry and transportation are still major sources of pollutants; CO_2 is the most important, due to influential role in global warming. A large part of CO_2 emissions are related to the consumption of fossil fuels as an energy source for the various production processes. Iraq has an abundance of all of cement's main ingredients: limestone, gypsum, and oil for fuel. Iraq has (14) cement factories grouped into three companies (except Kurdistan Region). Most of cement factories use heavy fuel oil for cement produced, which is make cement industry of more polluted industry to environment in Iraq [5]. The transportation sector is a vital and service sector and an important tributary of the national economy in all countries of the world and especially in Iraq and main source for air pollutants that release to the atmosphere. The total number of cars in Iraq until 2013 was (4515041) car with Kurdistan, while total number of cars in 2012 (3830187) car, by an increase of (17.9 %) [6]. Intergovernmental Panel on Climate Changes (IPCC) methods provides many techniques to watch the behavior of CO_2 emissions according to the equations and formulas available. These methods used in current research to evaluation of CO_2 emissions due to CP and transportation sector in Iraq during period (1970-2013).

Materials and Methods

The World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) jointly established the (IPCC) in 1988, to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information

relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation [7]. IPCC guidelines 2006 provide method of work for a broad range of users to estimates GHG_S emissions. IPCC guidelines deal with a few key concepts:

1. Emission Factors (EF): EF is generally expressed in the form of a quantity of GHG_S emitted per unit of energy or consumed fuel.
2. Anthropogenic Emissions: Anthropogenic emissions are a result of human activities.
3. Tiers: A tier represents a level of methodological complexity. Usually three tiers are provided. Tier 1 is the simplest and most accessible. Tier 1 used in current study because Iraq has not (EF) yet. So, used default (EF).

Eq. (1) represents CO_2 emissions based on cement production [8].

$$CO_2\text{Emissions} = \left[\sum_i (M_{ci} * C_{cli}) - IM + EX\right] * EF_{clc} \qquad (1)$$

Where:

CO_2 Emissions: emissions of CO_2 from cement production, tonnes (t)

Mci: mass of cement producer of type *i*, t.

Ccli: clinker fraction of cement of type *i*, fraction.

IM: imports for consumption of clinker, t.

EX: exports of clinker, t.

EFclc: EF for clinker in the particular cement, (t CO_2/t clinker)

Clinker is intermediate product in cement manufacturing and the main substance in cement. Clinker is the result of calcination of limestone in the kiln and subsequent reactions through burning. CO_2 emissions from cement production are result both from energy use and from the decomposition of calcium carbonate (CaO) during clinker production [9]. Calculates CO_2 emissions from transportation sector by eq. (2) [10]:

$$\text{Emissions} = \sum_a [\text{Fuel}_a * EF_a] \qquad (2)$$

Where:

Emission: emissions of CO_2 (kg)
Fuel $_a$ = fuel consumed in Terajoul (TJ)

EF_a = emission factor (kg/TJ).

a = type of fuel (e.g. kerosene, diesel, natural gas, LPG etc…).

CO_2 emissions are expressed in Gega gram (Gg) is equal to (1000 tonnes). There are conversion factors for each fuel type to convert consumption fuel quantities from (Gg) to energy unit in (TJ) for used it to estimate GHG emissions [2].

Statistical method that used for determines the ratio of increase of CO_2 emissions follows the eq. (3) [11]:

$$XR = \left(\frac{x_{Max.}}{x_{Min.}} - 1\right) * 100\ \% \qquad (3)$$

Where: *XR*= ratio of increase of CO_2 emissions (%)
χ = maximum and minimum values of CO_2 emissions.

Simple linear regression and correlation (r) used to find the relationships between variables and their strength in current study. Coefficient of determination (R^2) is descriptive measure to interpret the regression equation and expresses the strength of the relationship between the x and y variables. R^2 can vary from $(0 \leq r^2 \leq 1)$. The value of (r) is such that $(-1 \leq r \leq +1)$. The positive and negative signs are used for positive linear correlations and negative linear correlations, respectively [12]. Data sources used in current research are based on: data of CP based on of ministry of industrial in Iraq, and International Energy Agency (IEA) data used in transportation sector from (1970-2013).

Results and Discussion

CP in Iraq has suffered to multi fluctuations during the case study, which reflected on CO_2 emissions that released from it, figure (1). Therefore, correlation coefficient between CO_2 emissions and CP is a weak positive (0.23). CP has highest value (12000 kilo tonne (kt)) recorded in years 2013, while the lowest value was (500 kt) in 1991. Emissions of CO_2

depends on the amount of CP. Therefore, CO_2 emissions have the highest value (4680 Gg) in 2013, while the lowest value (195 Gg) in 1991. *XR* of CO_2 emissions showed in table (1). Both of CP and CO_2 emissions grew gradually in Iraq from (800 kt and 312 Gg) respectively in 1970, to higher value (4100 kt and 1599 Gg) in 1978 for the 1st time period, even fell slightly in 1980 (3400 kt and 1326 Gg). *XR* of CO_2 emissions increased clearly during this period to reach 325 %. CP and CO_2 emissions raised a lot in 80s and early 90s, reaching the highest value (11400 kt and 4446 Gg), respectively in 1989, supported by an increase in domestic demand and exports. CP suffered sharp decline in 1991 (500 kt) and CO_2 emissions fell to (195 Gg), therefore, *XR* of CO_2 emissions decreased to its lowest value 48 % during the 2nd time period, because of the results of the First Gulf War. CO_2 emissions recovered again in the mid-nineties and the beginning of the third millennium, due to increased domestic demand reached to high value (6800 kt and 2652 Gg) in 2002. *XR* of CO_2 emissions during the 3rd time period recorded 162 %, but this value less than expected, due to the difficult events that faced Iraq in that time.

CP and CO_2 emissions reached to highest values in 2013 (12000 kt and 4680 Gg) respectively, during the 4th time period, despite the significant decline in 2007 (1900 kt and 741 Gg), due to the internal situation in Iraq. *XR* of CO_2 emissions reached a record value 532 %, because the high productivity of the cement factories in Iraq for local demand. There are three max peak values for CO_2 emissions and CP in years (1984, 1989, 2002 and 2013) showed in figure (1).The greatest value among them when CP is high was recorded in 2013.

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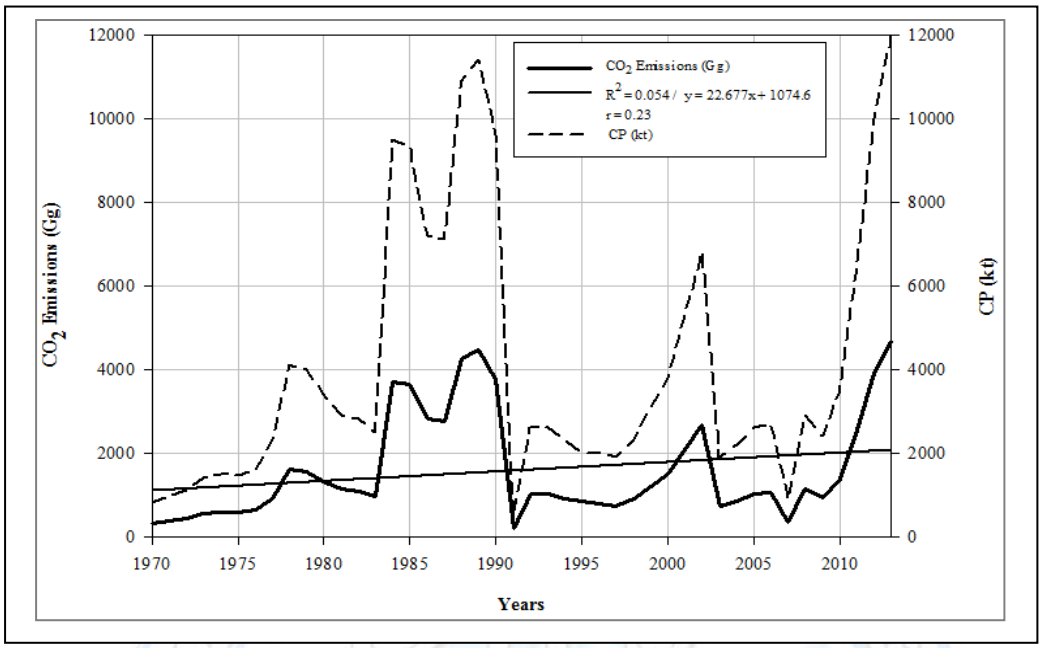

Figure 1: CO_2 emissions (Gg) and CP (kt) during case study

Table 1: *XR* of CO_2 emissions and CP

Time Period	*XR* CO_2 Emissions (%)
1970-1980	325
1981-1991	48
1992-2002	162
2003-2013	532

The transportation sector is very important source of CO_2 emissions. The development of transportation sector depends on number of cars and their consumption of fuel. The emissions of CO_2 (Gg) due to transportation sector in Iraq during (1970-2013) showed in figure 2.

CO_2 emissions have grown significantly due to transportation during the study period from (2200 Gg) in 1970 to (39000 Gg) in 2013, because of increase in the number of different types of transportation and consumption large quantities of fuel. Therefore, the value of R^2 of

CO_2 emissions is very high (R^2 = 0.94). The fuel used in the transportation sector generally was the gasoline and gasoil/diesel, where adding materials special to gasoline prevent popping, causing incomplete combustion of fuel and emission of large amounts of pollutant gases and heavy metals.

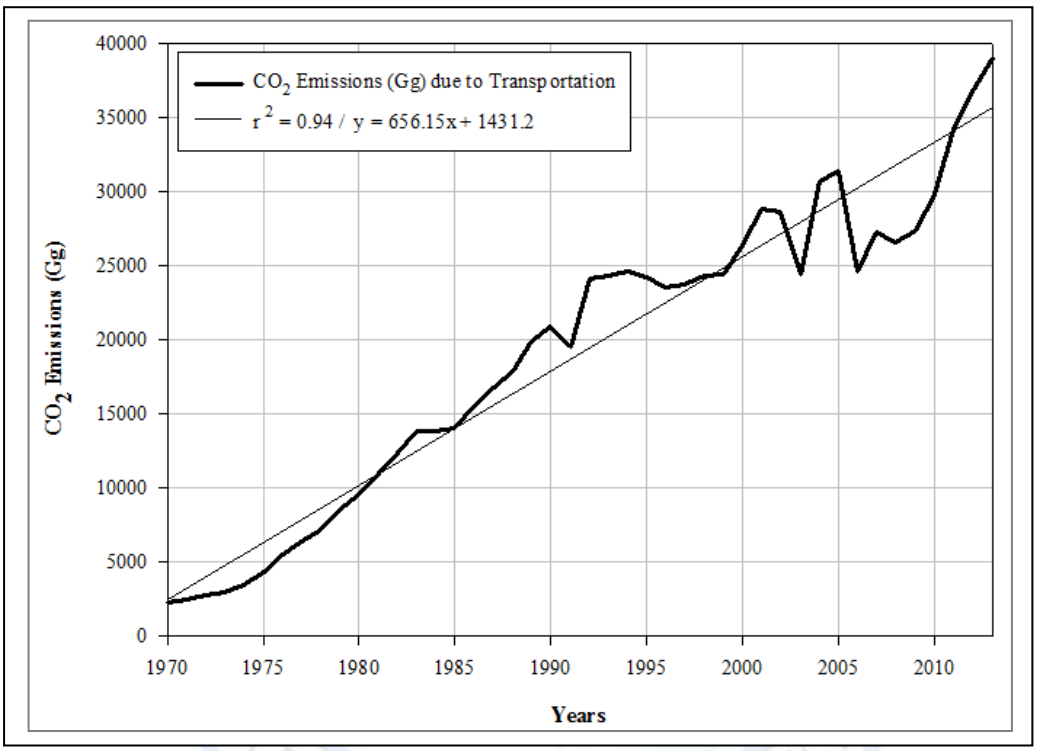

Figure 2: CO_2 emissions (Gg) due to transportation sector in Iraq

Table 2 shows *XR* of CO_2 emissions to transportation sector. *XR* of CO_2 emissions seems clear for the 1st time period, where the value was 330 %, which explains the continued rise of CO_2 emissions during this period. Although CO_2 emissions were stability from the beginning of the 2nd time period, but it suffered a sudden drop in 1991, severely affected on *XR* of CO_2 emissions for this time period, where the value was 78 %. CO_2 emissions were increased again in 1992 and continued slowly throughout the 90s (3rd time period), recorded the lowest *XR* of CO_2 emissions was 19 %, which was less than expected because of the economic situation during this period.

Table 2: *XR* of CO_2 emissions for transportation sector

Time Period	*XR* of CO_2 Emissions (%)
1970-1980	330
1981-1991	78
1992-2002	19
2003-2013	60

CO_2 emissions increased at the beginning of the 4th time period (30630 Gg) in 2004, due to import large numbers of cars to Iraq after 2003, mostly were used, causing an increase in CO_2 emissions. In spite of the low CO_2 emissions in years 2006 and 2008 during 4th time period, due to crisis of fuel, *XR* of CO_2 emissions was recorded 60 %, due to improved living condition for a large number of the population in Iraq, which has increased from owning cars. As well as opening Iraq to the world , the freedom to travel and the opening of airports for travelers, all of that and other increased of CO_2 emissions during the 4th time period of the current study. The percentage of share of CO_2 emissions from (CP and transportation sector) during (1970-2013), showed in figure 3, where percentage of CO_2 emissions from CP increased from 1 % in 1970 to 4 % in 2013. The reason of this increased is grow of CP due to increased of local demand in Iraq, due to the opening up of Iraqi market, especially after 2003. The percentage of share of CO_2 emissions from transportation in Iraq increased from 10 % in 1970 to 30 % in 2013.

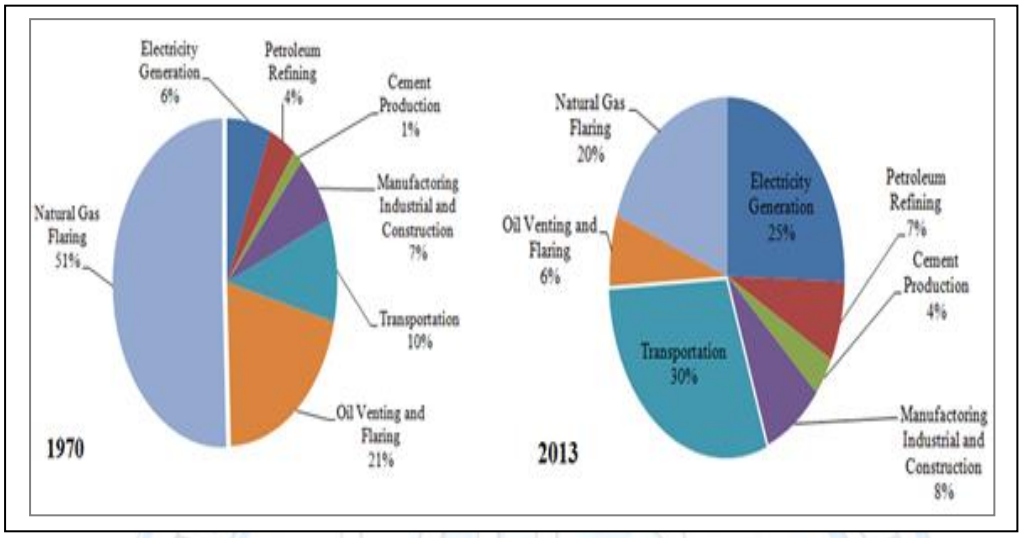

Figure 3: Percentage of share of CO_2 emissions from (CP and transportation sector) during (1970-2013)

Conclusions

1. Results shown multi fluctuations of CP, which reflected on the CO_2 emissions that released from it during the case study. Therefore, correlation coefficient between CO_2 emissions and CP is a weak positive. Iraq became importer of cement after was exporter of cement in 70s and 80s of 20th century. The percentage of share of CO_2 emissions from CP increased from 1 % in 1970 to 4 % in 2013.
2. CO_2 emissions due to the transportation sector have grown significantly during (1970 -2013), because of increase in the number of different types of transportation and consumption large quantities of fuel. The value of R^2 of CO_2 emissions is very high (0.94).The percentage of share of CO_2 emissions from transportation in Iraq increased from 10 % in 1970 to 30 % in 2013.

3. The development of CP and reduction CO_2 emissions released from it in Iraq may occur using the modern technologies in CP to decline of CO_2 emissions and protection of environment.
4. Replacing fuel oil that used in CP by natural gas fuel to decrease CO_2 emissions.
5. Improvement of fuel qualities that used in transportation sector, especially gasoline and gasoil/diesel because large using in cars.
6. Using natural gas in transportation sector to reduction CO_2 emissions and other pollutants, and for conservative of environment cleaning.

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