Emissions Investigating of Carbon Dioxide Generated by the Iraqi Cement Industry

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Abstract

The most used material in the world after water is concrete, which depends mainly on its manufacture of cement leading to the emission of carbon dioxide (CO2), flying dust, and other greenhouse gasses (GHGs) resulting in pollution of the atmosphere. The emission of CO2 from cement production is approximately 5% of the global anthropogenic CO2. This research focuses on investigating the amount of CO2 emission from the Iraqi General Cement Company plants includes the cement factories of Kirkuk, Al-Qa’em, Fallujah, and Kubaisa, using the GHGs Protocol Measures Program (specifically cement based-method). The data required for cement production was provided by the Iraqi Ministry of Industry and Minerals throughout 25 years. The results showed that the largest amount of CO2 emissions cumulatively over 25 years was from the Kubaisa plant with an average emission amount of approximately 7,613,605 tons/25 years. While the lowest cumulative amount of emission was by Fallujah cement plant represented by about 868,341 tons/25 years. On the other hand, the highest and lowest production amount was from Kubaisa and Fallujah plants at 105% and 0.6% in 1989 and 2008 respectively relative to the design capacity. Shifting to renewable and clean energies that limit the amount of CO2 emitted to the atmosphere is highly recommended, although this requires facing problematic challenges.

Keywords: Carbon dioxide; emission; atmosphere, cement industry
1 Introduction

Greenhouse gases (GHGs) are available in the atmosphere which characterized by their ability to absorb infrared rays, which helps to increase the atmosphere temperature and thus contribute to global warming: water vapour, Carbon Dioxide (CO$_2$), Nitrous Oxide (N$_2$O), Methane (CH$_4$), Ozone (O$_3$), and Chlorofluorocarbons (CFCs)(1). The CO$_2$ is considered one of the most important gasses of GHGs. There are three main anthropogenic sources of CO$_2$ emissions to the atmosphere; oxidized fossil fuels, deforestation and carbonate analysis (2). The cement industry is the major contributing impact to air pollution and the associated negative effects on humans.

The Energy Technology Perspectives (ETP) predicted the rapid growth in the global demand for cement production of about 2.9% per year for the period from 2003 to 2050. This will guide to increasing the worldwide economy in 2050 by 3.6 times higher than current today (Figure 1-a).

Cement production is a major source of carbon dioxide emissions, due to the large use of coal or fossil fuels to operate clinker furnaces (3-5). More than 150 countries worldwide produce cement (6, 7) and/or clinker, which is the main input material in cement. Global estimated CO$_2$ emissions to the atmosphere from the total cement plants of about 5% (8, 9). The key factor for the industry is cement since it represents the primary material to produce concrete which utilized in structures, building material, tunnels, dams and other civil engineering construction industries (10-15). Emissions causing by the release of CO$_2$ during the calcination of limestone, the main raw material used in cement production. CO$_2$ emissions from the total cement plants are estimated for the period from 1840 to 2000 (Figure 1-b).

![Figure 1: (a) Worldwide Demand of cement (1970-2050), and (b) Worldwide atmospheric CO$_2$ and cement production (1840-2000) (6, 16)](image)

High levels of CO$_2$ in the atmosphere contribute more damage than benefits to the Earth (7). Generally, the benefits of carbon dioxide can be summarized by the growth of trees and other plants with very green leaves. While the negative impacts are numerous, including global warming, rising sea levels, melting ice, ocean acidification, and ice loss in the Arctic Sea, which leads to violent tropical storms (17).
Sunlight penetrates the atmosphere in the form of ultraviolet rays and visible light. Some of these rays are bounced back into space in the form of infrared or heat. CO$_2$ molecules reflect these long wavelengths to the Earth again by absorbing the infrared radiation. The result is an increase in Earth's temperature. Scientists recognise that the blame is not on the Sun and volcanoes for climate change.

According to the Intergovernmental Panel on Climate Change (IPCC). CO$_2$ emissions from volcanic are a maximum of 0.01 compared to the anthropogenic emissions of CO$_2$ released by humans since 1750 (2, 18). Air-polluted carbon dioxide is distinguished from other forms of pollution as a rapidly spreading. Its impact is not limited to the source region (as in the case of other polluting gases), but extends to neighbouring and remote areas and even globally due to its effect to the atmosphere. Unlike other forms of pollution (water, solid waste, etc.), the CO$_2$ emission cannot or is difficult to be contained after it leaves the source. Thus, it must be controlled or treated before it goes out into the atmosphere since it is often multiple sources and invisible to the naked eye.

Globally, one of the most important problems facing researchers is the availability of data regarding the quantities of CO$_2$ emission from cement production. It has been documented that some worldwide assessments have been significantly exaggerated (11). Therefore, this research has demonstrated the quantities of CO$_2$ emitted from Iraqi General Cement Company factories for 25 years by cement based-method due to the importance of cement industry for the local, regional and global levels in the construction and other economic sectors (19), resulting in toxic emissions, solid waste and the scraping of agricultural lands,

2 Cement Industry in Iraq and Cement production process

Cement manufacturing in Iraq is considered one of the oldest and strongest domestic industries that have an impact on the national economic perspective because of its direct relationship with the works of urban renaissance in terms of establishing projects and housing complexes (20). This industry is gradually growing according to the plans drawn up by the public and private sectors. The Iraqi factories can produce 32 million tons annually. Besides, there are plants in progress that will add new quantities. There are about 18 government factories and more than 5 private sector factories in Iraq. It is worth noting that most of the factories are suspended since 2014 due to armed operations, economic issues and financial austerity.

Global cement factories including Iraq produced million tons of CO$_2$ emissions and great pollution to the environment through its primitive dust emission techniques (19, 21, 22). It was documented that the emission of dust and the accumulation of solid waste from Iraqi cement plant (such as Kirkuk plant) threat the current and future generations due to the large quantities that were emitted at levels exceeded the much-permitted level (23, 24). Although cement factories in some governorates, such as Najaf and Kufa, were constructed away from farms and residential neighbourhoods, the expansion of the two cities and agriculture near factories over the years and the increase in the number of residents caused an environmental contradiction in those areas.
The cement manufacturing requires many processes (Figure 2) including the calcination process, heating the calcium carbonate or limestone (the principal raw material used to produce cement) at a temperature of 1400 °C (11).

\[ \text{CaCO}_3 + \text{heat} \rightarrow \text{CaO} + \text{CO}_2 \]

This leads to break the carbonate and release CO₂ to the air. To reach these temperatures, huge quantities of fossil fuels were burned leading to another emission of CO₂.

**Figure 2: Flowchart of cement production and corresponding GHGs emissions (22, 25, 26)**

### 3 Atmospheric Concentration of Carbon Dioxide

Human activities have changed the atmospheric concentration of CO₂ (27). Many researchers are pursuing to decrease the CO₂ concentration in the atmosphere to control the steady increase in Earth's temperature. The CO₂ ratio should be kept at around 380 ppm. The increase in CO₂ concentration is considered one of the most critical and serious issues facing the world, especially after the massive industrial revolution that occurred in the twentieth century. Currently, the concentration of CO₂ exceeds more than 417 parts per million (ppm) in the atmosphere (Figure 3-a). Whereas, in 1958, was about 315 ppm (Figure 3-b). In other words, 102 ppm during 62 years.

Due to the growing millions of tons of CO₂ gas in the atmosphere based on the expansion of various human industrial activities (28), it is expected that this trend will continue to escalate (Figure 3-b). Fresh air contains 0.03% of CO₂ of the air volume. Thus, any incline or decline caused by human or nature leads to quantitative or qualitative changes in these natural components and accordingly cause inevitable pollution.

No one knows for sure the consequences or the effects of the rapid increase in the concentration of CO₂ in the atmosphere in the next decades. Scientists realize that CO₂ causes the increase in atmospheric temperature, sea levels, ocean acidity and Earth's climate change. Pollution scientists believe that if the increase in the flow of this gas to the atmosphere remains, this will lead to a rise in the global temperature and may result in melting ice in the Polar Regions, sea-level rise, floods and a great disruption in the ecosystem.
Figure 3: Concentration of (a) current global CO$_2$ and (b) Historical annual CO$_2$ emission, 1955-2020 (www.CO$_2$.earth)

4 Study Area

The geographical locations for the cement factories were taken from the official website of the Iraqi Ministry of Industry and Minerals. The plant coordinates (longitudinal and altitude) were placed, demonstrated and illustrated by GIS and remote sensing techniques using ArcMap software (29, 30). The study area involves the Iraqi General Cement Company factories, which consists of Kirkuk, Al-Qa'em, Fallujah, and Kubaisa cement plants as shown in Figure 4. The period was chosen for 25 years from 1989 to 2013 based on the available data. The reason for not including the years after 2014 to the current date of this study, the interruption of production in these plants due to armed conflicts in the study area as well as the poor economic situations of the country.
5 Methodology

Emission portfolios and release impact evaluations for the cement industry can be determined according to two categories of evidence, previous literature information or actual measurement such as NOVA or Gasmet devices (Figure 5). This would provide noticeably with various results. In situ evaluation affords a best-integrated method. But considering the factional correlation of data management is respectful as well (27).

Figure 5: Measurements devices of gaseous pollutants

Annual production data for four cement factories were explored. Records were collected from the Iraqi Ministry of Industry and Minerals, General Cement Company for each plant. Installed both at the stack and the boiler output since the production of clinker is the peak energy- and emission- severe progression in the manufacturing of cement, accounting for more than $80–85\%$ of the overall environmental impact score.

In this research, the GHGs Protocol Initiative tool was adopted utilizing the cement-based method. This protocol establishes a unified comprehensive global framework for measuring and managing greenhouse gas emissions from private and public sector operations and mitigation procedures. One of the most important international accounting tools is the GHG Protocol, which is the most tool used by government and business leaders to understand, measure and manage greenhouse gas emissions.

This method calculates emissions from the calcination of calcium carbonate and the combustion of organic carbon in the raw mixture. The following equation and Table 1 were used to calculate the CO$_2$ emission according to the cement-based method (31):

$$CO_2\text{Emission} = P_{\text{cem}} \times \frac{\text{Clinker}}{\text{Cement}} \times \frac{\text{RM}}{\text{Clinker}} \times \frac{\text{CaCO}_3\text{ equivalent}}{\text{RM}} \times \frac{\text{CO}_2\text{ (m. w.)}}{\text{CaCO}_3\text{ (m. w.)}}$$

Where,

$P_{\text{cem}} =$ mass of cement produced

Clinker = mass of clinker

Cement = mass of cement

RM = mass of raw material

CaCO$_3$ equivalent = mass of CaCO$_3$ equivalent

CO$_2$ (m.w.) = molecular weight of CO$_2$

CaCO$_3$ (m.w.) = molecular weight of CaCO$_3$
Table 1: Default value (to be used only when plant-specific values are not available)

| Material                                                      | Percentage |
|---------------------------------------------------------------|------------|
| Clinker to Cement Ratio (%) - 100% Portland output            | 95%        |
| Clinker to Cement Ratio (%) - Portland Pozzolana cement       | 75%        |
| Clinker to Cement Ratio (%) - Portland Slag cement            | 55%        |
| Tonne of Raw Material per Tonne of Clinker                     | 1.54       |
| CaCO₃ Equivalent to Raw Material Ratio (%)                     | 78%        |

The annual cement production data for the factories of Iraqi General Cement Company is presented in Table 2, including the Kirkuk, Al-Qa’em, Fallujah, and Kubaisa cement plants throughout 25 years from 1989 to 2013. Taking into account that the study factories have suspended the production after 2013 due to the armed terrorist conflicts and the challenging economic circumstances of the government.

Table 2: Cement production by the Iraqi General Cement Company (http://icsc.gov.iq)

| Year | Quantity of cement produced (ton/year)* |
|------|-----------------------------------------|
|      | Kirkuk | Fallujah | Al-Qa’em | Kubaisa |
| Design capacity | 2,000,000 | 1,000,000 | 291,000 | 2,000,000 |
| 1989  | 1,285,696 | 227,093 | 90,367 | 2,098,311 |
| 1990  | 1,296,513 | 188,746 | 164,611 | 1,915,201 |
| 1991  | 156,481 | 40,636 | 0 | 518,572 |
| 1992  | 276,480 | 100,208 | 10,046 | 1,003,150 |
| 1993  | 237,930 | 83,144 | 163,674 | 905,887 |
| 1994  | 197,286 | 79,518 | 79,915 | 853,581 |
| 1995  | 86,320 | 51,762 | 66,763 | 590,875 |
| 1996  | 128,477 | 41,600 | 83,502 | 331,300 |
| 1997  | 201,607 | 61,439 | 146,070 | 379,406 |
| 1998  | 162,173 | 62,844 | 178,905 | 366,703 |
| 1999  | 368,324 | 72,874 | 258,396 | 469,240 |
| 2000  | 495,370 | 81,861 | 324,800 | 620,320 |
| 2001  | 636,193 | 113,120 | 371,491 | 863,394 |
| 2002  | 866,937 | 154,398 | 413,814 | 799,783 |
| 2003  | 274,953 | 54,110 | 185,875 | 202,831 |
| 2004  | 216,371 | 48,871 | 123,282 | 197,497 |
| 2005  | 373,695 | 57,956 | 135,830 | 245,913 |
| 2006  | 439,355 | 19,161 | 162,109 | 211,174 |
| 2007  | 341,945 | 5,266 | 154,193 | 251,940 |
| 2008  | 325,174 | 1,620 | 148,740 | 277,150 |
| 2009  | 193,954 | 11,717 | 206,130 | 208,531 |
| 2010  | 309,707 | 14,717 | 416,803 | 142,792 |
| 2011  | 292,572 | 65,671 | 429,089 | 169,694 |
| 2012  | 415,384 | 39,476 | 639,606 | 479,504 |
| 2013  | 516,890 | 51,604 | 779,511 | 1,060,695 |
6 Results and Discussion

In this research, the calculation of CO₂ emissions was achieved using the cement-based method outlined earlier in the research methodology. Data was entered for the cement produced for each cement factory (Kirkuk, Fallujah, Al-Qa’em, and Kubaisa cement factories) as shown in Table 3. It is observed as well from Figure 6 that the highest amount of the CO₂ emission was in 1989 from Kubaisa cement factory, reaching 1,053,565 tons annually, with a noticeable output rate of approximately 105%. In contrast, the lowest emission amount was in 2008 from the Fallujah cement factory, regardless of the stoppage data in 1991 of the Al-Qa’em cement factory. Figure 6 shows the amount of CO₂ emission from the cement factories of the Iraqi General Cement Company (1989-2013).

Table 3. CO₂ emissions details of the study area

| Location       | CO₂ emissions (ton/year) | Kirkuk  | Fallujah | Al-Qa'em | Kubaisa |
|----------------|--------------------------|---------|----------|----------|---------|
| Maximum Value  |                          | 650,981 | 114,024  | 391,394  | 1,053,565 |
| The highest percentage relative to the design capacity | 65%  | 78%  | 78%  | 105% |
| Minimum Value  |                          | 43,341  | 813      | 5,044    | 71,696  |
| The lowest percentage relative to the design capacity | %4  | 0.6% | 1%  | 7% |
| The cumulative amount of CO₂ emissions during 25 years | 5,069,111 | 868,341 | 2,878,765 | 7,613,605 |
| Design capacity |                          | 1,004,203 | 146,112  | 502,102  | 1,004,203 |

Figure 6: CO₂ emissions from the Iraqi General Cement Company plants (1989-2013)
In general, from a cumulative point of view, it is clear from Figure 7 that Kubaisa cement factory has the largest cumulative amount of CO2 emissions during the study years during the period (1989-2013) with a cumulative emission amount of approximately 7,613,605 tons of CO2, and the lowest cumulative amount of CO2 emissions for the same period of Fallujah cement factory, equals to 868,341 tons of CO2.

The production of cement causes many pollutants to be released into the atmosphere and inevitably leads to problems such as air pollution (32). The Iraqi government should supervise the process of manufacturing cement industries as regulatory authorities, and therefore these factories will implement the protocols and maintain the balance. Besides, factories should also install advanced machines for measuring toxic gases released into the atmosphere (32).

7 Conclusions

Greenhouse gas emissions accounting is a very significant part of greening. It is important to keep track of the emission values and allow the company to compare its performance throughout the industry years. Cement production plays a huge role in Iraq’s economy if the government uses this industry in the correct ways like the developed countries such as the USA, China and India. Although this industry has a positive role in economic development, it poses threats to environmental health.

The current study aims to investigate the CO2 emission amount from the Iraqi General Cement Company plants throughout 25 years. Cement based-method is a vital technique in this range. It was observed that the highest recorded amount of CO2 emissions was in 1989 from the Kubaisa cement factory, as it reached 1,053,565 tons per year, with a production rate of approximately 105% compared to the design capacity. On the contrary, the lowest emission rate was from the Fallujah cement factory of 813 tons in 2008. Based on the obtained results, the lowest percentage with a production rate of 0.6% of design capacity was
from Fallujah Plant. Besides, Kubaisa factory has the largest cumulative amount of CO₂ emissions during the study years (1989-2013) of approximately 7,613,605 tons of CO₂. Whereas, the lowest cumulative amount of CO₂ emissions was from Fallujah cement factory of 868,341 tons of CO₂ for the same period.

8 Recommendations

Carbon Dioxide emission can be minimized in several ways: Utilizing renewable and clean energies are highly recommended as alternatives to reduce the amount of CO₂ emitted to the atmosphere. Also, study and implement methods of reserving CO₂ even though this requires to face many challenges. CO₂ gas treatment employing up-to-date technology before it is released into the atmosphere. Moreover, recycling and converting CO₂ into other useful chemicals products, such as methanol, which is used as an alternative and environmentally friendly fuel. It is worth mentioning that several organizations, Georgia Institute of Technology, the University of Calgary in Canada, the University of Columbia, the Center for Advanced Technology in Arizona and the Swiss Federal Institute of Technology in Zurich, proposed to absorb part of the CO₂ from the atmosphere just as the forest trees do.

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