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# The Chemical Behavior of Greenhouse Gases and its Impact on Climate Change in Iraq

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**Abstract**

Iraq is one of the countries in the Middle East most facing the impact of climatic changes, the most important of which are high average temperatures, decreasing amounts of precipitation, drought, and desertification. Methane ($CH_4$) is a greenhouse gas emitted by human activities and has a direct impact on the climate, absorbing part of the heat into the atmosphere and preventing its leakage into space, which leads to an increase in air temperature. This phenomenon is known as global warming. Carbon dioxide ($CO_2$) is one of the greenhouse gases, which is constantly released into the atmosphere from natural sources, is transparent to the light rays coming from the sun where it does not absorb in the field of ultraviolet radiation, but absorbs infrared from the earth, thus is considered one of the greenhouse gases and forms around 60% of greenhouse gases. The research aims to study the chemical behavior of the effect of greenhouse gases on climate change in Iraq. Data were taken from satellites recorded by the European Center for Medium-Range Weather Forecasts. Copernicus Atmosphere Monitoring Service (CAMS) ECMWF reanalysis for the global climate and weather. This study was selected for the different regions of Iraq (Northern, Central, Western, Southern), during the period (2003-2017). The scientific benefit of the study lies in knowing the behavior of emissions of chemical pollutants and greenhouse gases and the extent of their impact on the atmosphere after it has become a problem of interest in its effects on ecosystems and human activities. The results showed an increase in the level of methane concentration in August, during which the maximum level of methane concentration was recorded with an increase of (1845 ppb) in the southern region, while the minimum for March was recorded at (1793 ppb) in the northern region. The results also indicated the level of carbon dioxide emission, during which the limit was recorded. The maximum increase was (397 ppm) for May in the southern region, while the minimum was recorded at a concentration level of (391.2 ppm) in the northern region. To address the problem of pollutant emissions and greenhouse gases, the techniques, behaviors, and policies that fall upon each individual must be followed, in addition to using the carbon footprint as an indicator that means determining the amount of greenhouse gas emissions, the most important of which is carbon dioxide resulting from burning fossil fuels, which reflects the extent of the individual's consumption of energy in various activities.

***Keywords:*** Chemical Behavior; Greenhouse Gases; Climate Change; Iraq.

## 1. Introduction

Global warming refers to the increase in the world's average surface temperature with an increase in the amount of $CO_2$ and some other gases formed in the atmosphere. Global warming refers to the impact of human activities on the climate, especially the burning of fossil fuels (coal, oil, gas) and large-scale deforestation that emits large amounts of greenhouse gases, the most important of which is carbon dioxide [1]. This happens by absorbing atmospheric gases such as carbon dioxide from the sun's energy and trapping it near the earth, which contributes to global warming. The maximum global warming will reach 1.5 $^{o}$C degrees of greenhouse gases due to human activities over the coming decades, where the least emissions of greenhouse gases cause the temperature to rise to a peak level of 1.5 $^{o}$C in 2030 [2]. It is likely to increase by 0.8 to 1.2 above pre-industrial gas concentration levels recorded in 2017, meaning that the rate of emissions increases by about 0.2 $^{o}$C to 0.3 $^{o}$C per

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decade [3]. $CO_2$ gas absorbs infrared and sends them at wavelengths ranging from (4.26-14.99) μm, so it is considered a greenhouse gas that has an important effect on the temperature of the surface of the earth, as well as the most important global warming gas. $CH_4$ is one of the greenhouse gases and is tens of times more powerful than carbon dioxide in heating (warming) the atmosphere, and the gas is responsible for about 30% of global warming. Also, methane is a short-lived climate pollutant, its life in the atmosphere is much shorter than the life of carbon dioxide gas, and it is more efficient at trapping radiation. Studying the effect of increasing the concentration of methane in the atmosphere on temperature variation using the data of the European Center for Medium-Range Weather Forecasts during the period (2003-2016) over Iraq using the data of the European Center for Medium-Range Weather Forecasts (ECMWF) [4]. The net anthropogenic influx of carbon dioxide comes from changes in land cover such as deforestation and cutting and burning of trees [5]. Study of the increase in the concentration of carbon dioxide in the atmosphere of temperature difference using satellite data recorded by the (ECMWF) and Giovanni reanalysis for NASA during the period (2003-2016) over Iraq [6]. Analysis and estimation of the annual trend in the concentration of carbon dioxide in Iraq for the period (2003-2016) using data taken from the Aqua NASA satellite [7]. Studying the effect of carbon dioxide, methane, and nitrous oxide emissions on agricultural lands and their impact on environmental pollution in Iraq after 2003 using neural networks [8]. Investigation of the causal structure between the effect of carbon dioxide gas, the total average global temperature, and the global radiative forcing during the period 1850 [9]. Increasing the concentration of carbon dioxide in the atmosphere on a large scale is a major factor in global warming [10]. The increase in carbon dioxide in the current atmosphere is caused by anthropogenic carbon dioxide emissions [11]. Analysis of the global carbon budget of carbon dioxide for human emissions and natural resources using special simulation models [12]. It is expected that during the next billion years, plants and animals will perish from the surface of the earth so that most of the carbon will be isolated under the earth's surface, which slows down the processes that lead to the liberation of carbon dioxide into the atmosphere [13]. Methane is the central to atmospheric chemistry and is a very important greenhouse gas [14]. Methane is a hydrocarbon and the main component of natural gas and abundant greenhouse gas, which makes it a major contributor to climate change, especially in the short term [15]. More than half of global methane emissions are emitted by human activities in three sectors (fossil fuels, waste, and agriculture) [16]. The climate temperature increase during the twenty-first century is expected to range between 1.0 °C and 3.7 °C resulting from increased future greenhouse gas emissions [17]. Verification of the positive reactions between global warming and the increase in the levels of $CO_2$ concentrations deduced from climate changes in the past, with the effect of the increase in anthropogenic emissions, which was enhanced by the rise in the levels of greenhouse gases and the increase in global temperature rates [18]. Most previous studies have pointed to the importance of $CO_2$ as the gas of life on the planet. Plants thrive better when $CO_2$ levels are high in the atmosphere or greenhouse gases, more $CO_2$ means more rates of photosynthesis and biomass production. For each type of plant [19]. Monitoring the impact of carbon dioxide in Iraq, after the increase in its concentration levels and the increase in greenhouse gas emissions resulting from human activities that greatly affected the climate, using data Atmospheric Infrared Sounder (AIRS) that showed an increase in carbon dioxide emissions in the ground during the spring and early summer months [20] [21] [22].

## 2. Experimental

### *2.1. $CO_2$ composition in the atmosphere*

A chemical compound that is symbolized by the chemical formula ($CO_2$), colorless and odorless, non-flammable, acidic, and easy to dissolve in water, it is one of the important gases in the atmosphere, its concentration averages 400 parts per million by volume, and its concentration varies between areas near the, in addition, the concentration of $CO_2$ varies according to the months of the year. In the northern hemisphere, the concentration of $CO_2$ is at its highest during the spring season, while it is at its lowest level in the autumn season. $CO_2$ is produced by the reaction of carbon with oxygen, as in the following reaction:

$$CO + O_2 \longrightarrow CO_2 \quad \text{..... (1)}$$

Where $\Delta H = -394$ kJ/mole.

This oxidation reaction occurs when all types of carbon-containing fuels such as methane (natural gas) are burned, in addition to coal, wood, and other organic materials. It also gives lime calcination when heated to high temperatures above (850 °C) $CO_2$. At the industrial level, $CO_2$ is produced in different ways at all levels, often in the form of a by-product from the production of ammonia in a process called Haber-Bosch, as well as from hydrogen gas production in the process of boosting coal and reforming steam in natural gas production plants, from during this, $CO_2$ is obtained from the water-gas displacement reaction, forming $CO_2$, as in the following interaction.

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \quad \text{..... (2)}$$

At the laboratory level, carbon dioxide is produced in the laboratory from the effect of hydrochloric acid on calcium carbonate, as in the following reaction:

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2 \quad ... (3)$$

*2.2. Methane gas and its impact on the environment*

Methane gas is a chemical compound of the simplest types of hydrocarbons, its chemical formula ($CH_4$) has no odor and is one of the most important types of fuel. It is considered one of the strong greenhouse gases emitted by human activities such as leakage from natural gas systems, in addition to natural sources such as wetlands, as it has a bad effect on the presence of $CH_4$ in the atmosphere and affects the abundance of other greenhouse gases such as tropospheric ozone, water vapor, and $CO_2$. In addition to natural resources such as wetlands, it also has effects on human health, crop yields, quality, and productivity of vegetation cover through its important role in the formation of tropospheric ozone. It can heat the atmosphere 25 times more than the effect of carbon dioxide. When one molecule of methane is burned in the presence of oxygen, one molecule of carbon dioxide and two parts of water are produced, as in the following reaction:

$$CH_4\,(g) + 2O_2\,(g) \longrightarrow CO_2\,(g) + 2H_2O\,(l) \quad ... (4)$$

Where $\Delta H = -891$ kJ/mole.

Also according to the following reaction:

$$6CH_4 + O_2 \xrightarrow{1500\ ^oC} 2H{\equiv}CH + 2CO + H_2O \quad ..... (5)$$

Most of the methane found on Earth is bio-methane produced by methane synthesis, a form of anaerobic respiration, and methanogens are found in landfills and other types of soil, ruminants, and low-oxygen sediments under the seabed and lakes, this process is characterized as being multi-step and energy is used by microorganisms, so the net reaction to form methane is as follows:

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O \quad ..... (6)$$

When $CH_4$ burns, it turns into methyl radical $CH_3$. Which turns into formaldehyde HCHO or $H_2CO$, after that, the formaldehyde is transformed into the formal radical HCO, which in turn forms carbon monoxide. This process is called thermal-oxidative decomposition, as in the following reaction:

$$CH_4 + O_2 \longrightarrow CO + H_2 + H_2O \quad ..... (7)$$

After the oxidative pyrolysis process, it oxidizes ($H_2$) to form ($H_2O$) and releases heat:

$$H_2 + \frac{1}{2}O \longrightarrow H_2O \quad ..... (8)$$

After that CO is oxidized to form $CO_2$ and more heat is released to form the following reaction:

$$CO + \frac{1}{2}O_2 \longrightarrow CO_2 \quad ..... (9)$$

In the presence of suitable conditions, $CH_4$ reacts with halogen radicals as follows:

$$X\cdot + CH_4 \longrightarrow HX + CH_3\cdot \quad ..... (10)$$

$$CH3\cdot + X_2 \longrightarrow CH_3X + X_2 \quad ..... (11)$$

At high temperatures (700-1100) and in the presence of a catalytic metal (nickel), steam reacts with methane to produce a mixture of carbon monoxide and hydrogen known as synthetic gas or syngas. As in the following interaction:

$$CH_4 + H_2O \longrightarrow CO + 3H_2 \quad ..... (12)$$

Also, rice fields produce large amounts of methane during plant growth, which leads to its emission in a large and subject to increase, and this is caused by human causes resulting from human intervention in it.

## 3. Materials and Methods

*3.1. Study area*

Iraq is located in the northern hemisphere, in the northeast of the Arab world to the southwest of the continent of Asia, at longitude (43 $^o$E), latitude (33 $^o$N), the total length of its land borders is 3,631 km, bordered by Turkey in the north with a length of 331 km. From the east, Iran, with a length of 1458, from the west, Syria, and Jordan, with a length of 181 km, Syria with a length of 181, from the south, Saudi Arabia and Kuwait, with a length of 249 km, and the total length of the coasts is 58 km, where its location led to the length of the day reaching an average of about 14 hours for the summer, while that rate decreases during the winter to approximately (10) hours, leaving clear reflections on the state of climate elements and their change between summer and winter. The geography of Iraq falls into four main regions: the western plateau, which extends along the region west of the Euphrates River and extends to the deserts of Syria, Jordan, and Saudi Arabia. The mountainous region constitutes a quarter of the area of Iraq. It is located in the northern and northeastern parts of Iraq. It extends from the east with Iran, from the west with Syria, and the north with Turkey. The sedimentary plain area extends from the city of Balad on the Tigris River and the city of Ramadi in the Tallatasud region on the Euphrates River from the north, the Iranian border from the east, and the desert plateau from the west, and includes the Ahwaz region. The undulating region represents the transition zone between the low plains in the south and between the

high mountains in the far north and north-east in Iraq, extending between the Tigris River north of the city of Samarra and the Euphrates River north of the city of Hit and extending to Syria and Turkey. As shown in Figure 1.

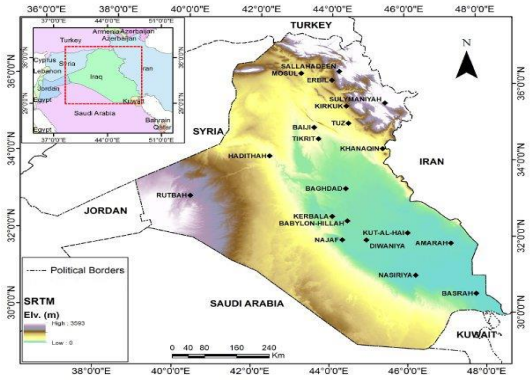



Fig. 1. Topographical map of Iraq.

*3.2. The Data Sources*

Copernicus Atmosphere Monitoring Service (CAMS) ECMWF reanalysis for the global climate and weather. Horizontal resolution (Reanalysis: 0.75°x0.75°), within the Temporal coverage (2003-2017), temporal resolution (Monthly).

**4. Results and Dissuasion**

*4.1. The behavior of the monthly long-term change of the mole- fraction (ppb) of methane over Iraq during (2003-2017)*

Figure ٢, indicates the behavior of $CH_4$ gas for the long-term monthly changes for all regions of Iraq (northern, central, western, and southern) over Iraq during the period (2003-2017). The results showed an increase in the average concentration of methane gas during the summer months (June, July, and August) It also recorded September a noticeable increase in its values, the highest concentration was recorded in the southern region for August at 1845 ppb, as it was recorded in the central region at 1836 ppb, the northern region 1830, the western region 1828 ppb. The results also showed a decrease in the concentration of methane gas during the winter months (January, February) almost in all regions of Iraq as a result of the decrease in temperature and precipitation, which is considered a good air cleaner from dust, gases, suspended matter in the air and other impurities and other pollutants released as a result of human emissions.

It is also noted that it recorded an increase in its concentration level during December, as it was recorded in the southern region at 1833 ppb, the central region at 1826 ppb, the northern region at 1820 ppb, and the western region at 1817 ppb. The reason for this increase is due to the increase in human activities as a result of the use of air-conditioning devices from air heaters during this season as a result of a significant drop in temperature, which increases the rate of methane emission. The months (April and May) also recorded a decrease in the level of methane gas concentrations as a result of the mild weather, as well as the decrease in human emissions and the moderation of temperatures during the spring season.

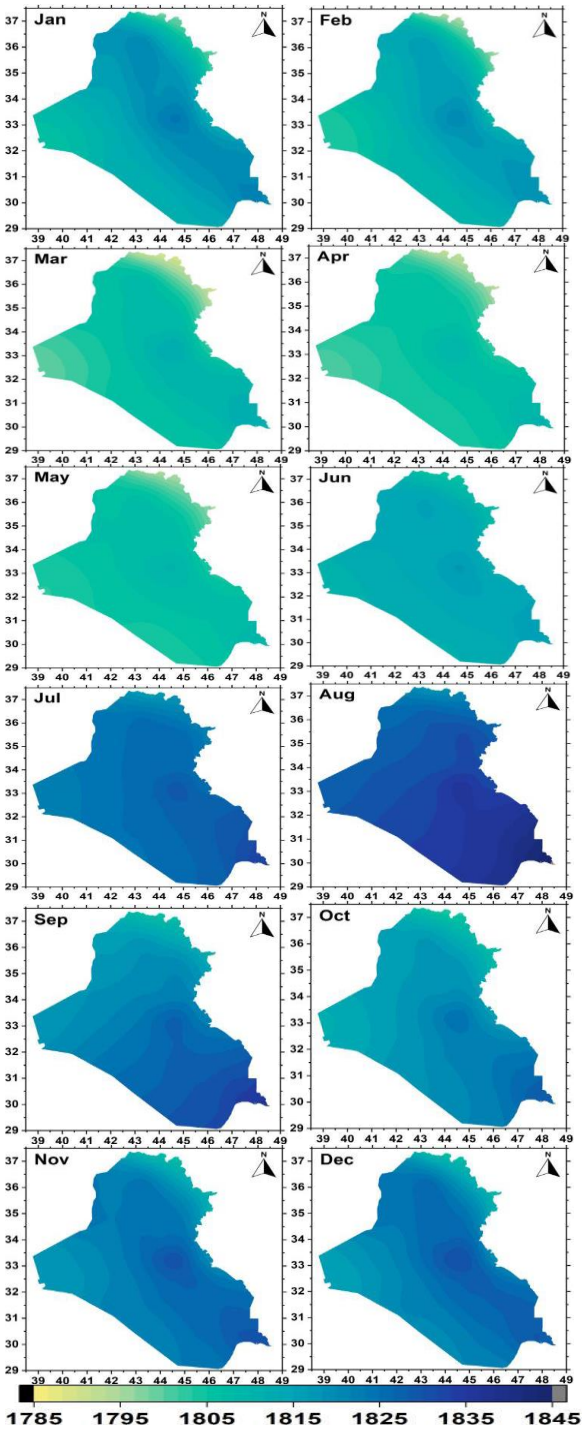



Fig. 2. Long-term monthly CH4 mole-fraction (ppb) over Iraq during (2003-2017).

*4.2. The behavior of long-term seasonal variations of the mole-fraction (ppb) of methane over Iraq during (2003-2017)*

Figure 3, shows the level of $CH_4$ gas concentration for the (northern, central, western, and southern) stations during the period (2003-2017). The results showed a decrease in the concentration of methane gas during the winter season, as the reason for this is due to the drop in temperature rates to their lowest levels during the winter season. This leads to a decrease in the concentration of gas, which indicates that there is a relationship linking temperature with the concentration of methane gas, as well as a decrease in the level of concentrations of other thermal pollutants in the atmosphere resulting from human resources. The lowest values of gas were recorded in the northern region with mountainous heights due to the low temperature in it to below 10 $^{o}$C, while in the southern region it is noted that it recorded a slight increase in the level of its concentrations. In the spring, the results indicate that the level of methane gas concentration has been recorded, decreasing in its rates in all regions of Iraq (northern, central, western, and southern), the lowest values for the level of methane gas concentration were recorded in the northern region at 1897 ppb. The summer and autumn seasons were recording the highest values for the level of gas concentration in all four stations, especially for the southern region, which was recorded at 1837 ppb, the central region at 1832 ppb, and the northern region at 1825 ppb, and the western region at 1820 ppb. The noticeable rise in the level of methane gas concentration during the summer season indicates an increase in temperature rates at high rates during this season due to the increase in the amount of solar radiation reaching the earth with the increase in sources of human pollutants due to the excessive use of some devices by humans, which increases the emission of chemical pollutants and the generation of greenhouse gases with the increase in chlorofluorocarbons that generate the emission of harmful gases into the atmosphere. In the autumn season, high concentrations of methane were recorded in the atmosphere as a result of the high temperatures during this season, which led to an increase in the concentration of the gas level during that season during the period (2003-2017).

*4.3. Analysis of the long-term monthly carbon dioxide trend behavior over Iraq during the period (2003-2017)*

Figure 4, shows the monthly variation in the $CO_2$ concentration values for the stations (Mosul, Baghdad, Rutba, and Basra) during the period (2003-2017). The results showed a discrepancy in the values of the carbon dioxide behavior level for all the four stations, each of which represented a specific region (Northern, Central, Western and Western). Respectively, the results showed a decrease in the levels of carbon dioxide concentration in December, January, and February, slow and little as a result of rainfall with cold high winds that form during this cold season of the year, which leads to a decrease in the level of carbon dioxide concentration in the atmosphere. Especially in the northern regions, which are characterized by the diversity of their terrain and the presence of high mountainous heights with a higher percentage of rain than the rest of the other regions. The maximum value of the carbon dioxide concentration level during the months (March, April, May, and June) that was monitored in the southern region was 397 ppm, it was also recorded in the central region at 396.6 ppm, the northern region at 395.9ppm, and the western region at 396ppm. In the months of (August, September, and October), it is noted that the level of $CO_2$ concentration in the atmosphere has decreased in its rates, and the minimum level of methane gas concentration was recorded in September, and it was at 392 ppm.

The reason for this difference in the levels of $CO_2$ concentration during the months and seasons of the year is due to the increase in the concentration of carbon dioxide during the spring and early summer seasons due to the increase in the food-making process carried out by the plant and its rates, as well as to the decrease in the removal of carbon dioxide resulting About cutting down trees and removing forests, with the increase in human and industrial activities. Due to Iraq's location in the northern hemisphere, this led to the level of carbon dioxide concentration being at its peak during the spring, as shown by the results in the average increase in its concentration for the months (March, April, May), which represent the months of spring, while it is at the lowest concentration level.

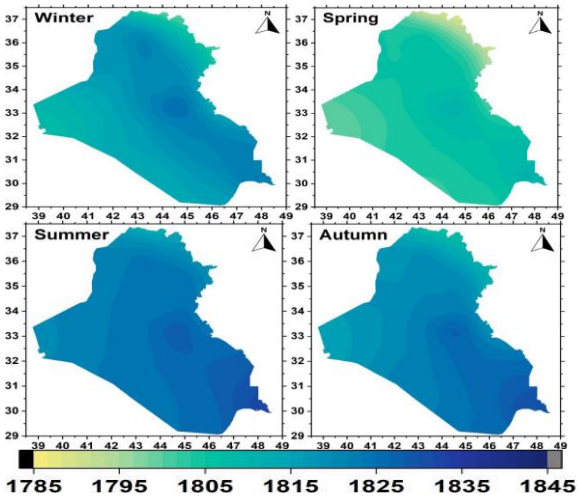



Fig. 3. Long-term seasonal $CH_4$ mole-fraction (ppb) over Iraq during (2003-2017).

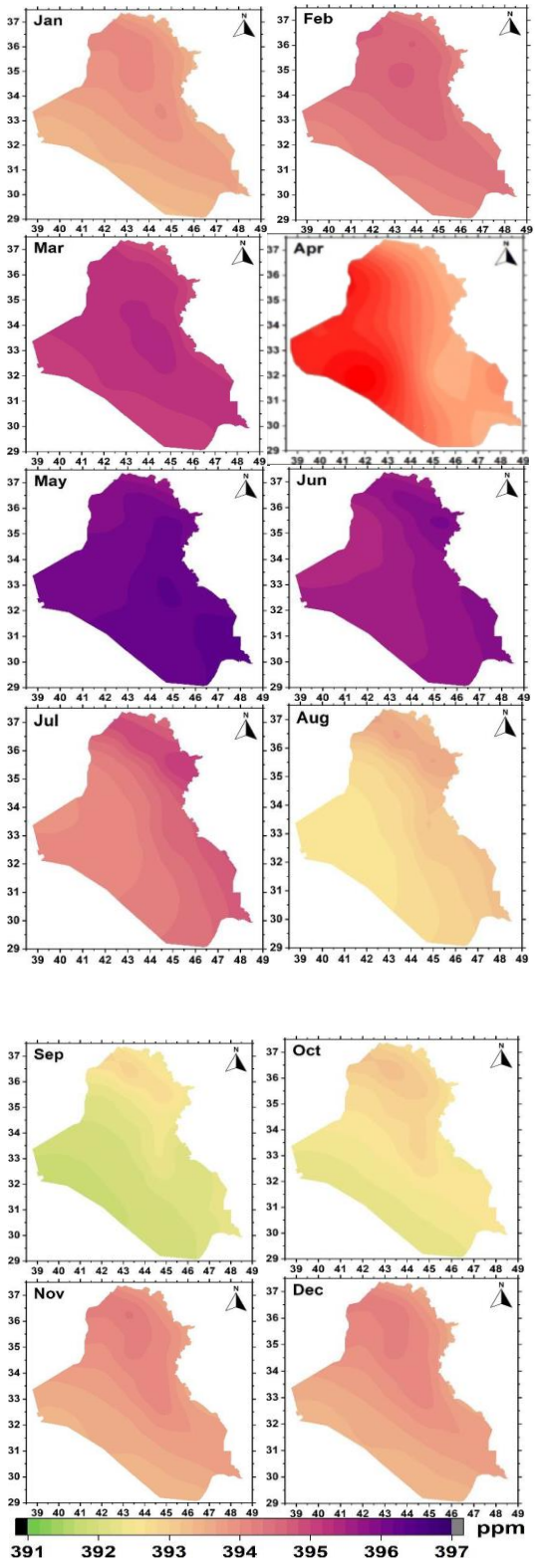



Fig. 4. Long-term monthly $CO_2$ concentration over Iraq during (2003-2017).

*4.4. Analysis of seasonal trends of long-term carbon dioxide concentrations over Iraq during the period (2003-2017)*

Figure 5, shows the seasonal trends of $CO_2$ concentration during the season (winter, spring, summer, and autumn), carbon dioxide concentrations faced several seasonal fluctuations, due to their exposure to different weather conditions, as well as the change in temperature rates, the diversity of terrain and the difference Characteristics. The results that were monitored for the winter season showed moderate levels of carbon dioxide concentration in most regions of Iraq, and the maximum level of carbon dioxide concentration recorded a clear increase in its rates for the spring season, due to seasonal temperature changes in addition to the nature of the climate, in addition to the increase in human and industrial activities with an increase in the rate of emissions of harmful gases caused by industrial pollution and an increase in the combustion of carbon fuels by humans. the nature of the climate, in addition to the increase in human and industrial activities with an increase in the rate of emissions of harmful gases caused by industrial pollution and an increase in the combustion of carbon fuels by humans, the nature of the climate. The levels of carbon dioxide concentration recorded an increase in its rates in the early summer, amounting to approximately 394, while a minimum decrease in its value was recorded for the autumn season, where it recorded a significant decrease due to the decrease in the rate of photosynthesis by plants and the processes of leaf fall by trees, as well as the change in the average temperature of Temperature for the months of September-October-November, as the reason for this is due to the temperature fluctuation on carbon dioxide concentrations during the seasons of the year.

*4.5. Analysis of the general trend of the time series of $CH_4$ mole-fraction (ppb) over stations (Mosul, Baghdad, Rutba, Basra) during the period (2003-2017)*

Figure 6, shows the annual variation of the time series of $CH_4$ behavior for each station (Mosul, Baghdad, Rutba, and Basra). The results show that there is an annual variation in the $CH_4$ concentration values above each station, and it was noted that the lowest recorded level was in the year 2003, and the maximum was in the year 2017 for all stations. The figure also shows that all concentrations represented an upward and increasing trend in the behavior of $CH_4$.

In the Mosul station, Figure 6(a), it was noted that the lowest level of $CH_4$ concentration was recorded in 2003 at about 176.0 ppb, it was also noted, that the continuation of the increase in $CH_4$ concentrations during the time series, in the second half of 2008 the increase in $CH_4$ concentration reached about 182.5 ppb, in 2010 the value of the increase amounted to

about 181.7 ppb, in 2013 it was recorded at a concentration level of 184.8 ppb, the maximum was recorded in 2017 for a concentration level of 186.9 ppb. In Baghdad station, Figure 6(b), the lowest level of $CH_4$ concentration was recorded for the year 2003 at 176.9 ppb, in the year 2008 recorded an increase of 182.5 ppb, and in the second half of 2013, recorded the value of the increase in $CH_4$ concentration at 185.0 ppb, and in 2016 recorded about 185.8 ppb. The $CH_4$ extent registered for the level of $CH_4$ concentration in 2017 was about 186.9 ppb. In Rutba station, Figure 6(c), indicates the level of increase in $CH_4$ concentration, the lowest level recorded for the year 2003 at a concentration level of 175.9 ppb, noting the continuation of the increase in $CH_4$ concentration in the time series, for the second half of 2008 an increase of 181.9 ppb was recorded It was also recorded for the same period in 2013 at 184.9 ppb, while the maximum recorded was for the year 2017. The level of $CH_4$ concentration reached about 186.0 ppb. In the Basra station, Figure 6(d), shows the level of increase in $CH_4$ concentration. It was noted that there is a significant increase in the time series that represents the increasing trend in $CH_4$ concentration values. The lowest recorded level was for the year 2003 at the concentration level of 177.0 ppb, at the end of the year 2008 the value of the increase in $CH_4$ concentration at 183.8 ppb, the year 2011 183.5 in the last quarter of the year 2015 recorded an increase of 185.9 ppb, the maximum concentration of $CH_4$ recorded for the year 2017 was about 187.3 ppb. The reason for this increase is due to the nature of the desert climate of the Basra station, with a significant increase in the amount of pollutants and human emissions, as well as the presence of the Umm Qasr seaport in which giant international shipping vessels congregate, which leads to the emission of large quantities of polluted fuel with an increase in the concentration of air pollutants, as well as rates the high temperature, With the high humidity in summer, which leads to an increase in toxic fumes and gases emitted by ships, ships, fuel tankers and oil and gas refineries in the governorate due to the presence of oil fields there, in addition to large quantities of biofuel combustion processes as a result of the industrial plants located there, which This leads to an increase in air pollution and the generation of harmful bacteria as a result of the emission of those organic substances that pollute the air and the environment, which increases the concentration of methane gas and its composition in the atmosphere significantly. These years were represented because they represent the peak increase in the $CH_4$ concentration in the atmosphere during the period (2003-2017) in addition to the amount of the increase recorded annually according to the time series of the $CH_4$ concentration level.

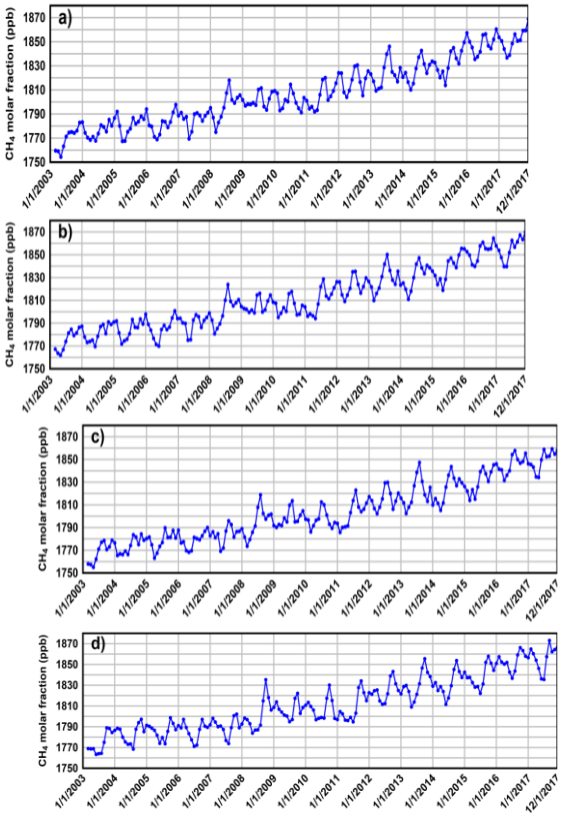
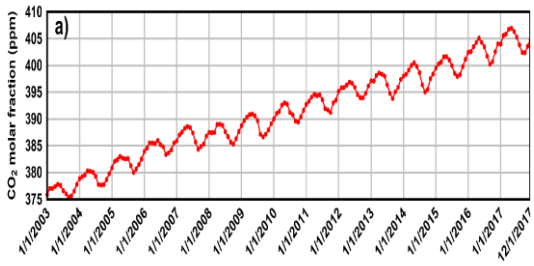



Fig. 6. Time series of $CH_4$ mole-fraction (ppb) over a) Mosul, b) Baghdad, c) Rutba, and d) Basra during (2003-2017).

### *4.6. Analysis of the general trend of the time series of $CO_2$ mole-fraction (ppm) for stations (Mosul, Baghdad, Rutba, Basra) during the period (2003-2017)*

Figure 7, shows the increasing upward trend in the values of the time series of the level of $CO_2$ concentration during the period (2003-2017) for all stations, at the Mosul station, the Figure 7(a), the lowest extent was recorded for the concentration of $CO_2$ was in the year 2003 at 375.1 ppm. The year 2010 also recorded an increase in $CO_2$ concentration during the first half of the year, specifically for May, which amounted to about 393.1 ppm, for the year 2014, recorded an increase of 400 ppm, and in 2016 the value of the increase for $CO_2$ reached 405 ppm, and the maximum concentration level for the year 2017 was about 406 ppm, in 2016, the value of the increase reached 405 ppm, the maximum level of the concentrate level for the year 2017 amounted to about 406 ppm. This shows that the general trend of $CO_2$ concentration tends to increase for the period (2003-2017) for Mosul station. In the Baghdad station, the Figure 7(b), the values of the increase that was recorded for the level of $CO_2$ concentration, the minimum that was recorded was for the year 2003 for January at the level of 375.2 ppm, noting the increase in the concentrations of $CO_2$, which recorded during

the year 2009 and increase of 392 ppm for May, as recorded in the year 2016 was 405 ppm, that the maximum recorded $CO_2$ concentration was in the year 2017 at 408 ppm. At Rutba Station, the Figure 7(c), shows that the level of $CO_2$ concentration is directed towards the increase as it is evident in the time series, the lowest extent that was concentrated in the year 2003 for December at the level of 375.1ppm, in the year 2009 the value of the increase in carbon dioxide concentration reached 391 ppm for May, and in the year 2014 he recorded an increase of 401 ppm, while the maximum level of $CO_2$ concentration was recorded during the year 2017 to record about 407ppm. In the Basra station, Figure 7(d), shows the upward trend of the time series values and the annual variation of the $CO_2$ concentration, the lowest recorded level was in the year 2003, it was about 375.2 ppm, and it also indicates that the trend of the increase in the concentration of $CO_2$ is constantly increasing. In 2015, the level of $CO_2$ concentration recorded an increase of 403 ppm, while the maximum level of $CO_2$ concentration was recorded at about 408 ppm. The reason for this increase is due to the rise in the temperature rates witnessed by Iraq during that period and its continuation to the present time as a result of the climatic changes witnessed by Iraq and the rest of the world In addition to the increase in solar activity and heating in the atmosphere, which caused high levels of $CO_2$ concentration in the atmosphere. The increase in the average temperature due to (radiative sequestration) resulting from the increase in the temperature that reaches the earth, which is known as the global warming phenomenon, has also caused an increase in the levels of $CO_2$ concentration in the atmosphere. It led to an increase in the level of $CO_2$ in the atmosphere. Human activities and wrong practices practiced by humans, such as the removal of trees and forests and the burning operations that Iraq faced as a result of the military actions and wars it witnessed during those years, in addition to the burning of fuels such as coal, oil, natural gas and cement production plants, all these factors led to an increase in the emission of second gas $CO_2$ at very high levels.



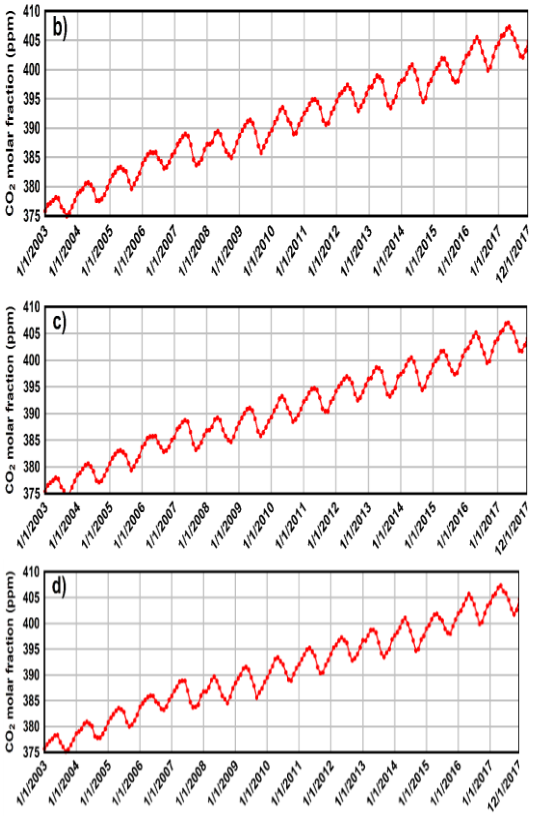




Fig. 7. Time series of $CO_2$ mole-fraction (ppm) over a) Mosul, b) Baghdad, c) Rutba, and d) Basra during (2003-2017).

*4.7. Analysis of the behavior of monthly changes in the level of concentration of carbon dioxide and methane gas for stations (Mosul, Baghdad, Rutba, and Basra) over Iraq during the period (2003-2017) using the method (Box plots).*

Figure 8(a), illustrates the monthly range of $CH_4$ gas concentration at the maximum and minimum levels recorded for the period (2003-2017) for stations (Mosul, Baghdad, Rutba, Basra) by the method of (Box plots). The results showed that the highest range of the maximum concentration of methane was recorded in the Basra station at 1875 ppb with the lowest at 1762 ppb, while the lowest range of $CH_4$ concentration was recorded in the Rutba station for a maximum at 1859 ppb with the lowest at 1857 ppb. Figure 8(b), illustrates the monthly range of $CO_2$ concentration for the stations (Mosul, Baghdad, Rutba, and Basra) for the period (2003-2017) by a method (Box plots). It recorded the maximum concentration of $CO_2$ in two stations (Mosul, Baghdad) at 408 ppm with a minimum of 375 ppm, while the lowest range was recorded in the two stations (Mosul, Rutba) with a maximum of 407 ppm, with a minimum of 375 ppm.

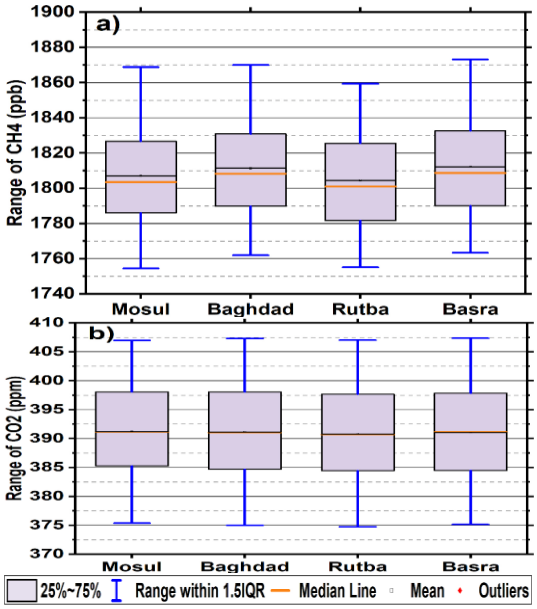



Fig. 8. Box plots of monthly a) CH4 and b) $CO_2$ for the four cities during (2003-2017).

## 5. Conclusions

Iraq is one of the countries in the Middle East most facing the impact of climatic changes, the most important of which are high average temperatures, decreasing amounts of precipitation, drought and desertification. Methane ($CH_4$) is a greenhouse gas emitted by human activities and has a direct impact on the climate, absorbing part of the heat into the atmosphere and preventing its leakage into space, which leads to an increase in air temperature. This phenomenon is known as global warming. Carbon dioxide ($CO_2$) is one of the greenhouse gases, which is constantly released to the atmosphere from natural sources, is transparent towards the light rays coming from the sun where it does not absorb in the field of ultraviolet radiation, but it absorbs infrared from the earth, thus is considered one of the greenhouse gases and forms around 60% of greenhouse gases. The aim of the research is to study the chemical behavior of the effect of greenhouse gases on climate change in Iraq. Data were taken from satellites recorded by the European Center for Medium-Range Weather Forecasts. Copernicus Atmosphere Monitoring Service (CAMS) ECMWF reanalysis for the global climate and weather. This study was selected for the different regions of Iraq (Northern, Central, Western, Southern), during the period (2003-2017). The scientific benefit of the study lies in knowing the behavior of emissions of chemical pollutants and greenhouse gases and the extent of their impact on the atmosphere after it has become a problem of interest in its effects on ecosystems and human activities. The results showed an increase in the level of methane concentration in August, during which the maximum level of methane concentration was recorded with an increase of (1845 ppb) in the southern region, while the minimum for the month of March was recorded at (1793 ppb) in the northern region. The results also indicated the level of carbon dioxide emission, during which the limit was recorded. The maximum increase was (397 ppm) for the month of May in the southern region, while the minimum was recorded at a concentration level of (391.2 ppm) in the northern region. To address the problem of pollutant emissions and greenhouse gases, the techniques, behaviors and policies that fall upon each individual must be followed, in addition to using the carbon footprint as an indicator that means determining the amount of greenhouse gas emissions, the most important of which is carbon dioxide resulting from burning fossil fuels, which reflects the extent of the individual's consumption of energy in various activities.

## 6. A Conflict of interest

There are no conflicts to declare.

## 7. Formatting of funding sources

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