Research Article

Spatial Variation In CO_2 Levels And World Health Organization In The City Of Najaf, Iraq

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Abstract

This study investigated carbon dioxide (CO_2) concentration levels in the city of Najaf. Fifty-two residential neighbourhoods and 14 diverse locations were selected. The presence of this gas in the neighbourhoods varied according to natural and human geographical factors, and there was a clear disparity between neighbourhoods in terms of whether levels were within or outside permissible limits according to international standards. The study of gas variation is an important part of determining air quality and identifying areas where gas concentrations are high, so that these can be addressed and limits set to reduce emissions. This is achieved through data analysis and the creation of maps using Geographic Information System (GIS) techniques to illustrate the spatial distribution of emissions.

Keywords: CO_2 concentration levels, international standards, World Health Organization.

Introduction

Carbon dioxide (CO_2) is a naturally occurring atmospheric gas that is colorless, odorless, and non-flammable. It forms an essential part of the Earth's carbon cycle and is continuously exchanged between the atmosphere, oceans, and terrestrial ecosystems (Jacob, 1999). In recent decades, however, atmospheric CO_2 levels have risen markedly as a result of human activities, particularly the large-scale burning of fossil fuels such as coal, oil, and natural gas for energy production, transportation, and industrial processes (IPCC, 2023; Global Carbon Project, 2025). While CO_2 exists naturally in the atmosphere, its increasing concentration enhances the greenhouse effect by trapping outgoing longwave radiation, which contributes to a gradual rise in global temperatures (Seinfeld & Pandis, 2016). This process is further intensified in urban environments where energy consumption is high and emissions from vehicles, generators, and industrial facilities are concentrated. Rapid urban expansion and population growth have therefore become key drivers of anthropogenic CO_2 emissions (WMO, 2024). In addition, the loss of vegetation cover and the conversion of natural land into built-up areas reduce the capacity of ecosystems to absorb atmospheric carbon dioxide through photosynthesis, allowing greater accumulation in the atmosphere (IPCC, 2023). For these reasons, monitoring CO_2 levels and understanding their spatial distribution are increasingly important for evaluating environmental quality and supporting urban planning policies aimed at reducing emissions and improving atmospheric conditions.

Research Problem

1. Does the spatial distribution of CO_2 vary between the neighbourhoods of Najaf?
2. Do the CO_2 levels recorded in Najaf fall within the environmentally permissible limits according to the standards?

Significance of the Research

The study of CO_2 is one of the most important topics of research, as it directly affects human health and the ecosystem, as well as providing insights into air quality and supplying institutions with accurate data to aid urban planning.

The aim of the research

1- Determination of CO_2 concentration levels at sampling sites distributed across 52 neighbourhoods and 12 complexes within the city of Najaf
2- Determining acceptable levels in accordance with international standards.
3- Representing this variation using GIS.
4- Assessing the environmental impact resulting from this variation and proposing measures to reduce emissions

Research hypotheses

1- Field measurements indicate that there is a variation in CO_2 levels between neighbourhoods.
2- There is a discrepancy between permissible and non-permissible levels in the data recorded in the neighbourhoods of the study area according to international standards.

Scope of the study

The spatial boundaries of the study area in the city of Najaf cover an area of 8,577.5 hectares. Geographically, it is situated at the intersection of the latitudes (0°29.50' 0°31.21' N) and longitudes (0°42.1 0°45.44°) east. Geographically, it lies at the southernmost tip of the northern section of the Iraqi sedimentary plain and on the southern edge of the Western Desert, 10 km from the Euphrates River, overlooking the Najaf Depression. It is the administrative centre of the Najaf al-Ashraf Governorate, bordered to the north by the city of al-Haydariya at a distance of 40 km, to the east by the city of Kufa at a distance of 10 km, and to the south-east by the city of Al-Manadhira at a distance of 25 km. (Fig.1).

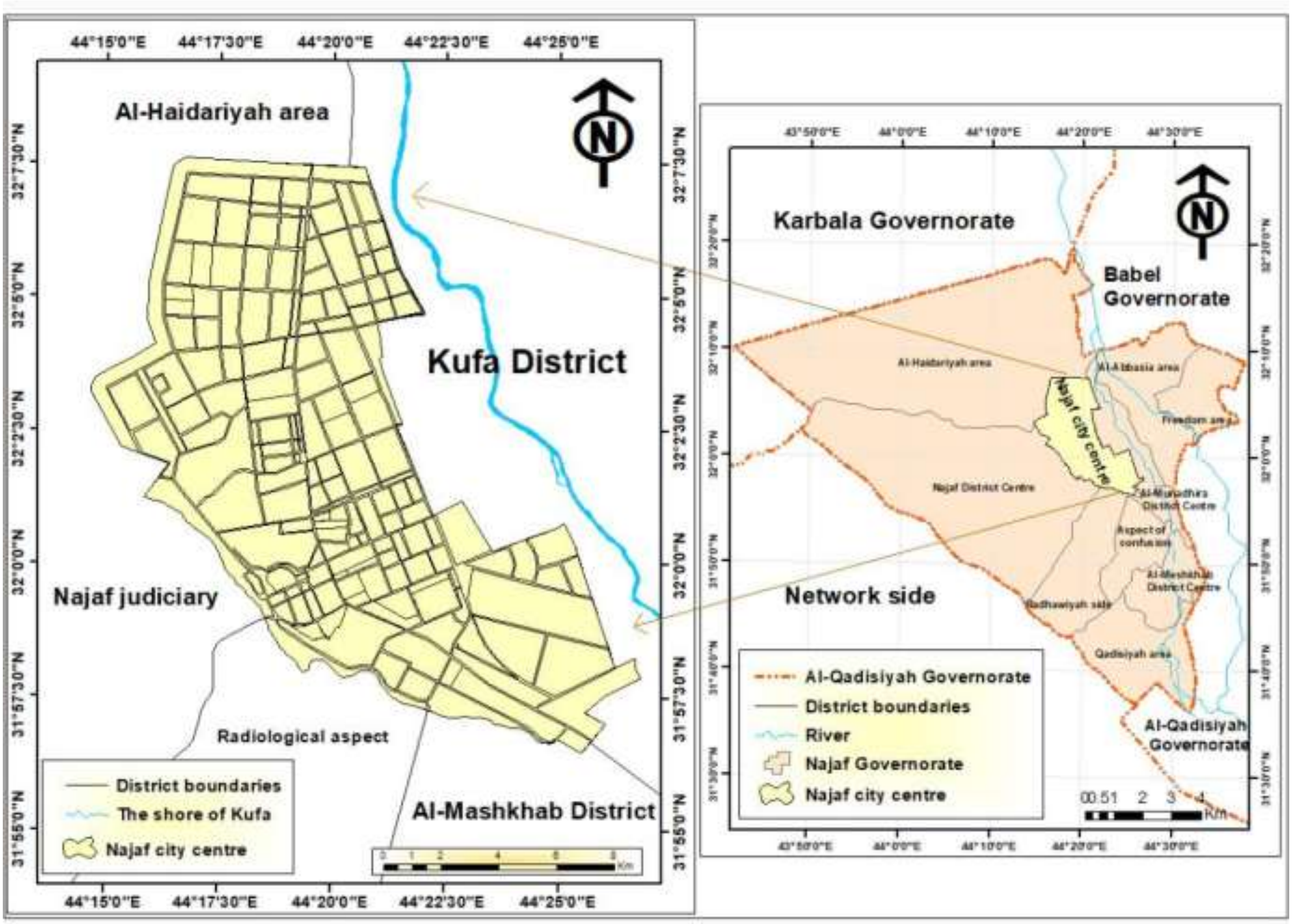

Figure 1 Location of the city of Najaf within Najaf Governorate and Iraq

Sampling sites in the study area

The field survey collected 290 samples from neighbourhoods within the study area, spread across 52 residential neighbourhoods and 14 housing estates. These locations were selected in a systematic, purposeful and methodical manner with the aim of representing variations in carbon footprint levels in terms of:

- proximity to industrial and construction pollution sources; · Traffic and transport.
- Proximity to waste management sites. Population density in the area.
- Proximity to power stations and generators.

The locations were accurately recorded using coordinate systems and by determining the longitudes and latitudes, as well as the air temperature and humidity at the time the sample was taken.

Assessment of carbon dioxide (CO2) levels in the city of Najaf:

Studying carbon dioxide (CO_2) levels in urban environments is a fundamental step within the framework of comprehensive environmental assessment. Furthermore, CO_2 is one of the primary greenhouse gases responsible for global warming, as it is produced by various fuel combustion processes—such as vehicle exhaust and industrial activities as well as domestic energy use. With this in mind, the analysis of carbon dioxide (CO_2) levels is scientifically necessary to identify the nature of the problems faced, and to reveal pollution levels and the impact of natural and human factors on them by comparing them with recognized international standards. The environmental assessment process requires accurate field data, obtained by collecting samples using air monitoring devices in neighbourhoods within the study area, to ensure reliable readings that contribute to a precise scientific interpretation of the environmental reality of the carbon footprint in the city of Najaf.
This assessment is based on World Health Organisation standards, as shown in Table 1, which states:

- Concentrations below 800 ppm: indicate good ventilation.
- Values ranging from 800 to 1000 ppm: represent an acceptable level.
- Values exceeding 1000 ppm: an unacceptable level.

Table (1): Carbon dioxide concentration standards in accordance with World Health Organisation guidelines

Environmental interpretation	Value in ppm	Concentration level
Indicates good ventilation and adequate indoor air quality.	Less than 800 ppm	Good ventilation
Represents the acceptable range for indoor air quality.	800–1000 ppm	Acceptable level
Indicates poor ventilation and deteriorating indoor air quality.	Over 1000 ppm	Unacceptable level

The field study and field measurements, which involved the analysis of carbon dioxide data, show that the total number of samples is divided into 133 samples falling within the permissible limit of less than 1,000, and 157 samples exceeding the permissible limit of 1,000. These have been categorised into three groups at the spatial analysis level:

1. The first category:
Low values were concentrated in the neighbourhoods of Al-Hanana, Al-Saad, Al-Iskan, Al-Quds and Al-Qadah, as well as the estates of Abu Tarab and Al-Zahra. This can be explained by distinctive environmental and urban characteristics, including low population density and limited industrial or commercial activity.

2- The second category:
Meanwhile, other neighbourhoods (Al-Adala, Al-Thawra, Jadida Al-Thalitha, Jadida Al-Rabi’a, Milad Al-Thani, Al-Nida’, Makrama, Al-Jazira, Al-Wafa’, Al-Hindiya, Al-Nasr), as well as the estates (Al-Sultan, Imad Sukkar, Al-Karar, Al-Amirat Thani) and areas (Al-Hawli, Al-Maqbara) showed high levels exceeding the permitted limit, reflecting a combination of factors including high population density, traffic congestion and industrial workshops.

3. The third category:
These included areas with internal divisions, such as (Al-Salam, Al-Ghari, Al-Jami’ah, Al-Furat, Al-Ghadeer, Al-Karama, Al-Ulama’, Al-Marahilin, Al-Hussein, Al-Sihah, Abu Khalid, Al-Muthanna, Al-Ishtiraki, Al-Amir, Al-

Ansar, Al-Harfiin, Aden, Al-Ma'alim, Al-Sawaq, Al-Zahra', Al-Shurta, Jadida Al-Awwal, Jadida Al-Thaniya, Milad 1, Al-Faw, Al-Askari, Al-Jam'iya, Al-Arouba, Al-Muhandisin, Abu Talib, Al-Rahma), as well as the estates (Al-Ghadir Village, Bayn Ma Bayn 2, 1, Al-Amirat 1, Qanbar) and the Old City, showed variations between samples, such as 3 versus 1 or 2 versus 2.
As shown in Table 2 and Fig. 2, the details of the carbon dioxide (CO_2) samples are as follows:

1- Highest concentrations: the highest value reached approximately (5000).
Spatial distribution: It occurred in various locations in the south-eastern and northern parts of the study area at sites (S218, S19, S220).
2. Lowest concentrations: The lowest value recorded was (343)

Spatial distribution: It appeared in the central and western parts of the study area at site (203)

Figure 2 the study area

The fact that CO_2 concentrations are high in some locations and low in others reflects the inverse relationship between the intensity of human activity and environmental degradation in areas experiencing high levels of environmental pressure resulting from concentrated emissions. This necessitates the implementation of sustainable development plans to achieve environmental balance in the study area (Fig. 3).

Table (2) Details of carbon dioxide sampling

Parameter	Number	Samples	Concentrations
Permissible	133	S1-S2-S3-S5-S6-S7-S9-S10-S11-S12-S13-S15-S16-S22-S23-S24-S25-S26-S32-S33-S34-S38-S39-S40-S41-S43-S44-S45-S46-S47-S48-S50-S51-S53-S54-S55-S56-S57-S59-S63-S64-S65-S66-S68-S69-S70-S71-S72-S73-S74-S76-S77-S78-S81-S82-S83-S84-S86-S87-S94-S95-S97-S100-S101-S102-S106-S113-S114-S115-S118-S126-S127-S129-S130-S141-S142-S150-S159-S165-S174-S176-S191-S192-S193-S195-S196-S197-S198-S199-S200-S201-S203-S204-S205-S206-S209-S210-S211-S212-S213-S215-S216-S226-S227-S229-S230-S233-S234-S235-S236-S237-S238-S247-S248-S249 -S251-S255-S256-S275-S276-S278-S279-S280-S281-S283-S284-S285-S288-S289-	Less than 1000 Ranged from 343 to 998
	157	S4-S8-S14-S17-S18-S19-S20-S21-S27-S28-S29-S30-S31-S35-S36-S37-S42-S49-S52-S58-S60-S61-S62-S67-S75-S79-S80-S85-S88-S89-S90-S91-S92-S93-S96-S98-S99-S103-S104-S105-	

Not permitted	S107-S108-S109-S110-S111-S112-S116-S117-S119-S120-S121-S122-S123-S124-S125-S128-S131-S132-S133-S134-S135-S136-S137-S138-S139-S140-S143-S144-S145-S146-S147-S148-S149-S151-S152-S153-S154-S155-S156-S157-S158-S160-S161-S162-S163-S164-S166-S167-S168-S169-S170-S171-S172-S173-S175-S177-S178-S179-S180-S181-S182-S183-S184-S185-S186-S187-S188-S189-S190-S194-S202-S207-S208-S214-S217-S218-S219-S220-S221-S222-S223-S224-S225-S228-S231-S232-S239-S240-S241-S242-S243-S244-S245-S246-S250-S252-S253-S254-S257-S258-S259-S260-S261-S262-S263-S264-S265-S266-S267-S268-S269-S270-S271-S272-S273-S274-S277-S282-S286-S287-S290	More than 1000 Ranged from 1,009 to 5,000

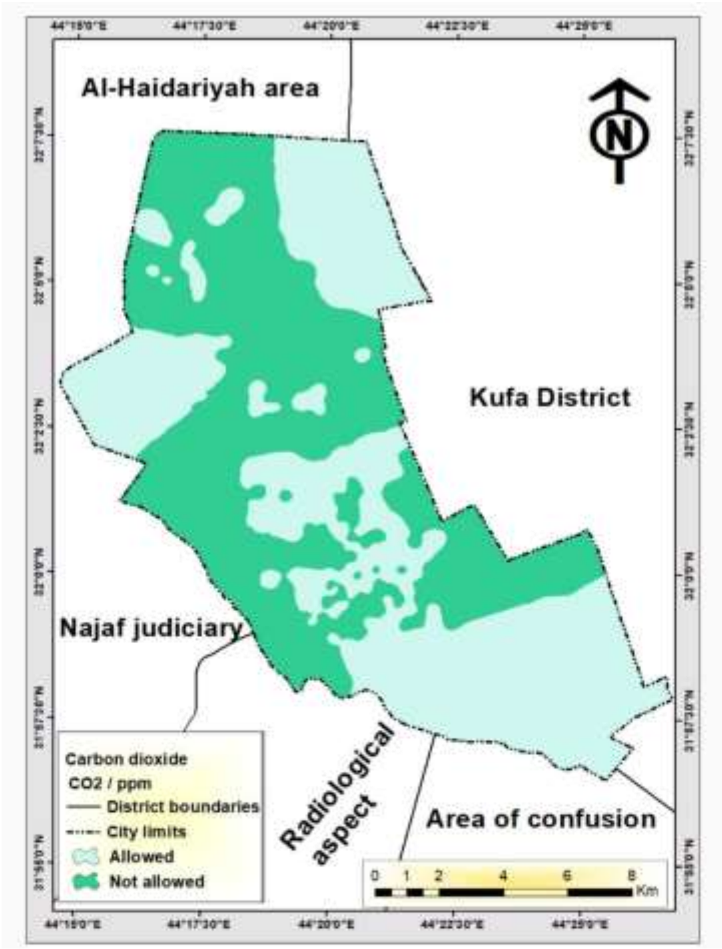

Figure 3 Comparison of carbon dioxide levels with the global standard

Assessment of the environmental impact resulting from variations in gas levels:

The observed rise in carbon dioxide levels, which in some locations has reached unacceptable concentrations exceeding 5,000 ppm, may lead to the creation of areas of environmental stress resulting from the concentration of emissions in densely populated neighbourhoods with high levels of traffic. This spatial variation may contribute directly to the greenhouse effect, as heat emitted from the Earth's surface is trapped in the atmosphere, leading to higher temperatures in these neighbourhoods compared to others. Furthermore, a lack of vegetation cover and the extensive use of fossil fuels for generators and vehicles may lead to a deterioration in air quality and a decrease in oxygen levels alongside an increase in carbon, which may directly affect human health and the integrity of the city's urban ecosystem. Therefore, there is an urgent need to direct sustainable development plans towards affected areas to ensure environmental balance and reduce these harmful emissions. The persistence of this imbalance, resulting from high levels of vehicle exhaust and the use of fossil fuels for generators, may accelerate the environmental impact on green spaces, as natural ecosystems may be unable to absorb these emissions. This worsening environmental situation may undermine the effectiveness of urban planning if measures are not taken to reduce sources of pollution, this necessitates the imposition of strict air quality standards that keep pace with the city's urban expansion, as high levels exceeding 1000ppm in most samples may trap hea t emitted from the ground and prevent its dispersion, which could raise temperatures in areas of high environmental stress.

Furthermore, this increase, caused by vehicle exhausts and generators, may lead to a deterioration in air quality and a reduction in oxygen levels, which could have a direct impact on human health and the integrity of the urban ecosystem.

Results

1. The study demonstrated a clear variation in the distribution of CO_2 across the neighbourhoods of Najaf.
2. Field measurements revealed that the majority of samples (157 in total) recorded concentrations exceeding 1,000 ppm, which is above international standards.
3. The recorded values ranged from a minimum concentration of 343 ppm to a maximum concentration of 5,000 ppm.
4. The high values in neighbourhoods such as Al-Adala, Al-Thawra and Al-Nida were linked to traffic congestion, high population density and workshops.
5. In some neighbourhoods (Al-Hanana, Al-Saad and Al-Iskan), low concentrations were observed, reflecting good ventilation and limited polluting activities.
6. The study concluded that the variation in gas levels reflects a direct relationship between the density of human activity and environmental degradation in the study area
7. Low and permissible values were concentrated in the neighbourhoods of Al-Hanana, Al-Saad, Al-Iskan, Al-Quds, and Al-Qadah, reflecting adequate air quality in these areas.
8. Meanwhile, areas of environmental stress in other neighbourhoods— including Al-Adala, Al-Thawra, Al-Nidaa and Al-Wafa—recorded high levels exceeding permissible limits, reflecting a deterioration in air quality and the accumulation of pollutants.
9. Elevated carbon footprint levels were associated with locations characterised by high population density, traffic congestion, industrial workshops, and waste management sites, as well as proximity to power stations and generators.

Recommendations

1- There is a need to expand tree planting around the city of Najaf to absorb excess CO_2 and increase the oxygen content in the atmosphere.
2- Encouraging the use of public transport to reduce the number of private vehicles, thereby reducing exhaust emissions in densely populated neighbourhoods.
3- By regulating generators and imposing strict environmental controls on private and government-owned generators, and requiring them to install filters to reduce carbon emissions.
4- Using renewable energy and supporting solar energy projects as a clean alternative for electricity generation in residential complexes to reduce reliance on fossil fuels.
5- Relocating polluting workshops and industrial activities from within residential neighbourhoods (such as the Artisans' Quarter and Aden) away from residential areas.
6- Raising environmental awareness by launching public awareness campaigns on the risks of carbon emissions and the importance of conserving energy.
7- Effective waste management by improving waste disposal methods and preventing indiscriminate burning near residential areas, which raises carbon levels.
8- Imposing penalties on factories and plants that exceed permitted emissions levels in accordance with international standards.

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