
Spatial Assessment of Indoor Air Pollution in Residential Buildings in Kufa City**Abd, Ghanim Sahib**

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Abstract

In this study, the concentration of carbon dioxide and volatile organic compounds was measured. Three residential neighborhoods were chosen in the city of Kufa, which were mentioned in the study area section, where 1% of the number of houses was chosen, results of (carbon dioxide, volatile organic Maysan residential neighborhood. the CO₂ concentration (ppm) varies between 367 ppm and 2450 ppm, with an average value of $1,064 \pm 59$ ppm. In addition, the VOC concentration (ppb) ranges from 44 ppb to 888 ppb, with an average value of 182 ± 21 ppb. The results (CO₂, voc) Al-Sayray residential neighborhood from 367 ppm to 1850 ppm with an average value of $1,083 \pm 111$ ppm. VOC concentration (ppb) ranged from 28 ppb to 870 ppb, with an average of 352 ± 65 ppb. and show the results (CO₂, VOC) from 435 ppm to 1950 ppm in the residential area of Altamar, Kufa, with an average value of 957.1 ± 97.479 ppm. The VOC concentration (ppb) ranged from 38 ppb to 788 ppb with an average value of 262.7 ± 224.48 ppb. Unfortunately, most of the results obtained in these were higher than the permissible limits set by the World Health Organization.

Keywords: Indoor air pollution, spatial analysis, residential units, air quality, environmental pollution, Kufa city

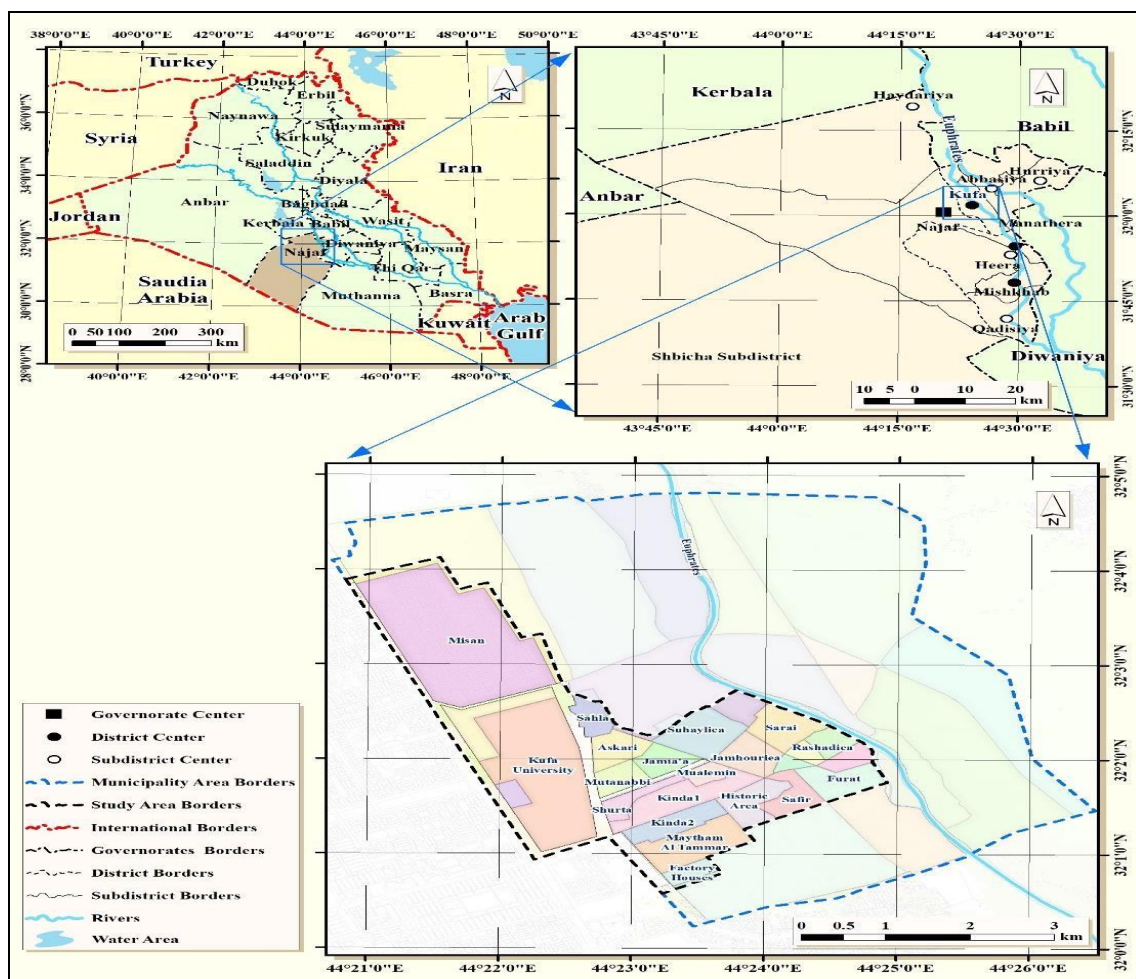
Introduction

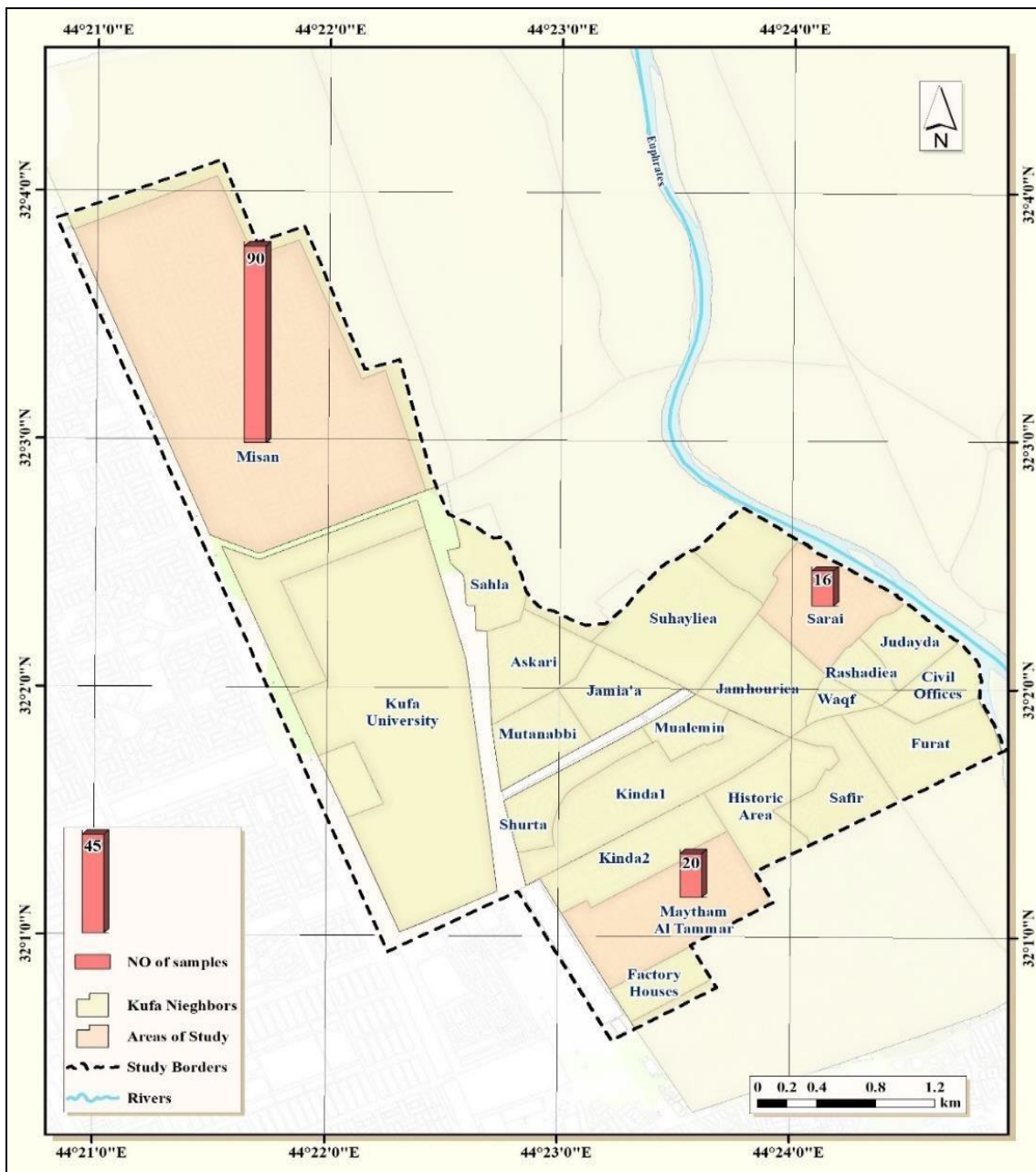
Air pollution is a serious environmental challenge that significantly affects human health and overall quality of life. In urban settings such as Kufa City, indoor air pollutants like carbon dioxide (CO₂) and volatile organic compounds (VOCs) have become a major concern due to their impact on residential environments. Understanding the spatial variation of indoor air pollution is essential, as it supports the development of effective strategies for improving indoor air quality and reducing associated health risks. This study aims to analyze the spatial distribution of CO₂ and VOC levels in residential areas of Kufa City, examine variations across different zones, identify the key factors influencing indoor air quality, and assess the health impacts associated with VOC exposure in homes. Evaluating indoor air quality through spatial patterns of CO₂ concentration in living spaces is particularly important. For example, Lu et al. proposed an innovative method for estimating air exchange rates and CO₂ generation based on occupant activity, highlighting the importance of understanding CO₂ dynamics in enclosed environments.

Spatial differences in CO₂ accumulation within indoor settings, such as classrooms, demonstrate significant variability across locations, emphasizing the need for detailed spatial analysis to identify high-risk zones requiring intervention. Reports from the Air Quality Expert Group further highlight the influence of CO₂ on indoor air quality, stressing the importance of continuous monitoring and control measures. The spatial distribution of VOCs is also critical, as their toxicity largely depends on concentration patterns within residential units. VOCs are commonly emitted from building materials, furniture, and household products, contributing to long-term indoor exposure. In addition, increasing industrial VOC emissions due to rapid urban and industrial development further necessitate spatial analysis to determine their distribution patterns.

However, detailed studies on the spatial distribution of VOCs remain limited, indicating a significant research gap. In Kufa City, spatial variability in urban air pollution intensifies indoor air quality issues, as indoor environments are strongly influenced by outdoor conditions. Previous studies on urban air pollutants have reported considerable spatial and temporal variations, highlighting the need for high-resolution assessments. The complex interaction between outdoor pollution sources and indoor exposure requires a comprehensive approach to air quality management, as uniform pollution assumptions are often insufficient for accurate assessment.

Indoor air pollution has serious implications for human health. Household air pollution is strongly linked to respiratory problems, impaired lung development in children, and increased incidence of lower respiratory tract infections. Short-term exposure to elevated pollution levels can reduce lung function and affect overall respiratory health, while long-term exposure is associated with chronic diseases such as stroke and cardiovascular disorders. Therefore, effective monitoring and management strategies are essential to mitigate the health risks associated with indoor air pollution.





Source: General Authority for Survey, Kufa Administrative City Map for the year 2023

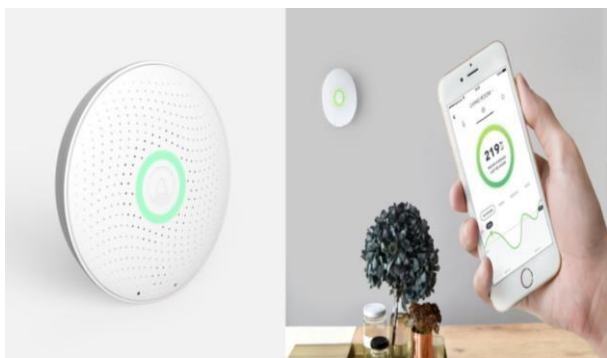
The city of Kufa was chosen, which is an Iraqi city and district center administratively affiliated with the Najaf Governorate in the Middle Euphrates region, south of the capital, Baghdad, and is about 156 km away from it and 10 km northeast of Najaf. Its population is estimated at about 230 thousand people, according to 2014 estimates. Three residential neighborhoods were selected from them. Three residential neighborhoods were chosen in the city of Kufa, which were mentioned in the study area section, where 1% of the number of houses was chosen, as shown in Table No. 1, during the time period from September 2023 to May 2024

Table 1: The measurement process was carried out using a radon device. Smart

Neighborhood	Number of houses
Maysan	90
Altamar	20
Al-Sayray	16

Measurement System

Placing the Wave Plus device at breathing height is ideal. It should be placed in rooms where people spend most of their time to get accurate readings on CO₂ and VOC levels an effective way of monitoring indoor air quality. Avoid placing it near ventilation points such as vents, fans, windows or doors if you want precise readings all through The Airthings View Plus device keeps track of various parameters related to indoor air quality, making it easier for users to access this information. When we compare different methods used in measuring CO₂ and VOCs with the Wave Plus Device, we are able to see what each method has to offer including its limitations: for example, traditional labbased analytical equipment might be expensive but would provide detailed data analysis while real-time monitoring methods like what is used by the Wave Plus Device give immediate results plus continuous tracking of VOC concentrations in breath ^[9]. In order to evaluate risks of VOCs, it is essential to have a good understanding of the concentrations present in the atmosphere. The Wave Plus Device has the ability to detect and measure VOCs in realtime; this means that it can pick up volatile profiles quickly and accurately. These profiles can be used for assessment of air quality and environmental risks. As such, when one is sensitive to CO₂ as well as VOCs, using deep-learning methods for data analysis helps in coming up with complex data patterns which lead towards enhancement of measurement precision a positive approach even toward urban emissions of VOCs and CO₂ micrometeorological techniques plus fast-response sensors can be used in real time. Measuring ultra-low concentrations of VOCs is not straightforward yet when considering technologies like the Wave Plus Device that are furnished with PID detectors, the light shines on their potential to actualize precise separation and quantification of VOCs. It marks an accomplishment for air quality monitoring; an innovation that could revolutionize how we control pollutants (number 8 and 9). An evaluation that compares different methods used in measuring Carbon Dioxide (CO₂) and Volatile Organic Compounds (VOCs) provides a revelation about what each approach brings on board as well as what it lacks. Such studies have shown that real-time monitoring techniques (similar to what the Wave Plus Device uses) can deliver immediate results on continuous tracking of VOC levels in breath information vital for determining air quality and efficacy of pollutant controls. Although it may be said that traditional lab-based analytical equipment offers elaborate data analysis, remember: the accessibility plus efficiency offered by these real-time monitoring technologies paint a promising picture for improving practices related to air quality surveillance. Yet difficulties still loom in accurately measuring ultra-low concentrations of VOCs which act as a major impediment to achieving exact quantification. However, despite these challenges, emerging technologies such as the Wave Plus Device that feature PID detectors signal hope towards surmounting these obstacles. The innovation in turn augments the separation and quantification of VOCs thus underscoring the potential contribution advanced monitoring devices can make in the field of air quality monitoring and pollutant control. In light of this, it is recommended that future research should focus on addressing limitations encountered when measuring VOCs at ultra-low concentrations; seeking more applications for real-time monitoring technologies and improving the effectiveness of air quality monitoring systems. These identified shortcomings are areas for improvement: through recognizing them and acting upon it within the research community we can continue promoting knowledge generation and adoption on innovations related to environmental monitoring issues.



Results

Table 2. Shows the results of (carbon dioxide, volatile organic Maysan residential neighborhood in the city of Kufa. The data and Figures (2) show that the CO₂ concentration (ppm) varies between 367ppm and 2450 ppm, with an average value of $1,064 \pm 59$ ppm. In addition, the VOC concentration (ppb) ranges from 44 ppb to 888 ppb, with an average value of 182 ± 21 ppb.

Table 2: Results of analysis of Maysan neighborhood samples.

No. House	CO ₂ (ppm)	Voc (ppb)	No. House	CO ₂ (ppm)	Voc (ppb)	No. House	CO ₂ (ppm)	Voc (ppb)
1.	099	544	31	099	09	61	594	90
2.	9919	977	32	9999	45	62	499	14
3.	1499	919	33	1549	49	63	700	44
4.	499	991	34	499	99	64	544	74
5.	499	955	35	444	71	65	9199	97
6.	905	944	36	095	04	66	9509	499
7.	444	944	37	777	94	67	1505	419
8.	9799	149	38	9999	44	68	1444	555
9.	9444	955	39	9411	04	69	597	499
10.	9549	449	40	9799	94	70	049	15
11.	9979	999	41	9009	74	71	944	979
12.	909	777	42	444	41	72	079	954
13.	975	904	43	199	54	73	544	915
14.	1544	949	44	794	90	74	497	955
15.	799	97	45	744	94	75	901	997
16.	704	50	46	479	49	76	579	907
17.	459	44	47	549	09	77	450	944
18.	9111	99	48	9945	94	78	714	949
19.	9919	77	49	9999	09	79	971	947
20.	1949	55	50	440	71	80	9549	905
21.	044	914	51	449	970	81	9909	911
22.	977	999	52	774	147	482	449	997
23.	444	07	53	449	944	83	549	944
24.	1999	94	54	9001	944	84	715	950
25.	9599	45	55	9479	597	85	9499	945
26.	9444	95	56	9477	914	86	044	997
27.	9959	99	57	9949	199	87	049	111
28.	9945	71	58	9909	144	88	944	55
29.	944	04	59	445	579	89	507	49
30.	455	49	60	909	944	90	459	74
Average							1,064±59	182±21

Source: The researcher based on the field study and the results of sample analysis.

Neighborhood in Kufa from 367 ppm to 1850 ppm with an ranged from 28 ppb to 870 ppb, with an average of 352 ± 65 average value of $1,083 \pm 111$ ppm. VOC concentration (ppb) appb.

Table 3: show the results (cO₂, voc)Al-Sayray residential

No. House	CO ₂ (ppm)	Voc (ppb(
1.	790	449
2.	799	799
3.	9499	440
4.	9749	54
5.	9595	17
6.	9497	00
7.	9544	149
8.	705	144
9.	074	145
10.	497	907
11.	590	945
12.	449	147
13.	770	507
14.	9499	470
15.	9455	44
94.	497	544
average	1,083±111	352 ±65

Source: The researcher based on the field study and the results of sample analysis

Table 4: Results of analysis of samples from the Maitham Al-Tamar neighborhood.

No. House	CO ₂ (ppm)	Voc (ppb(
1.	744	419
2.	719	499
3.	9999	140
4.	9049	44
5.	9449	47
6.	9544	990
7.	9907	949
8.	079	114
9.	475	155
10.	497	977
11.	590	905
12.	445	197
13.	770	557
14.	9479	440
15.	449	944
94.	790	944
99.	574	959
97.	409	914
90.	490	979
19.	544	994
Average	957.1 ±97.479	262.7 ±224.48

Source: The researcher based on the field study and the results of sample analysis

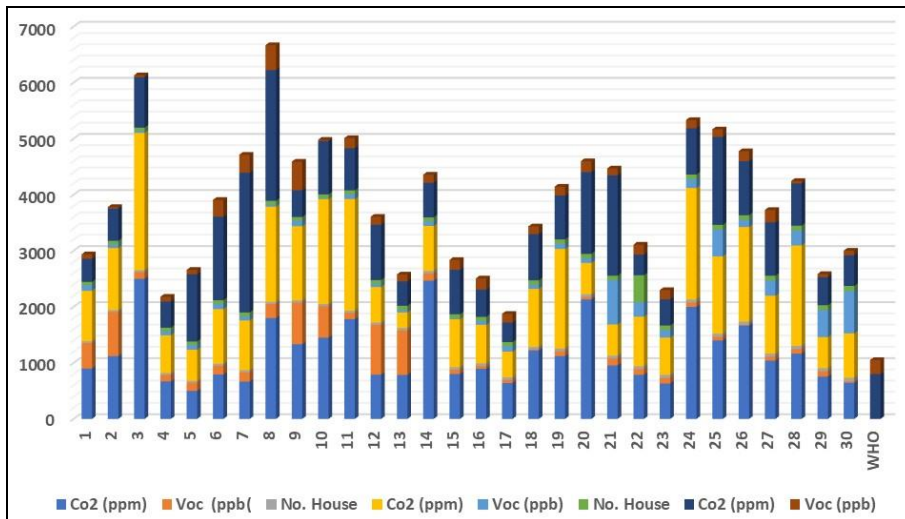
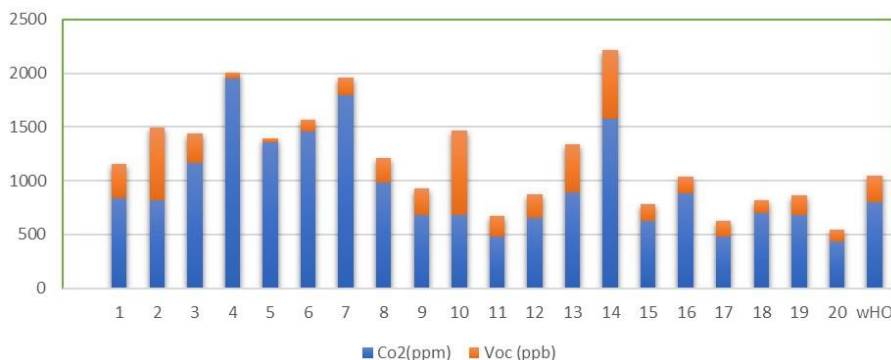
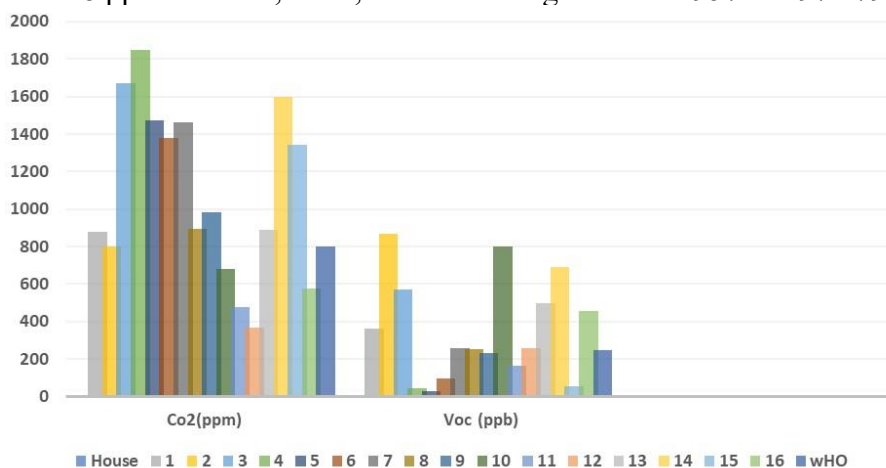


Fig 2: (CO₂, Voc₂) concentration is the in the In the Maysan residential neighborhood in the city of Kufa. with world average by WHO

Table 4. Table (4) and Figure (4) show the results (CO₂, ppm. The VOC concentration (ppb) ranged from 38 ppb to VOC) from 435 ppm to 1950 ppm in the residential area of 788 ppb with an average value of 262.7 ± 224.48 ppb. Altamar, Kufa, with an average value of 957.1 ± 97.479



Discussion

The results from Table No. (2, 3, and 4) depicted significant variations in carbon dioxide and volatile organic compounds concentrations among the three residential neighborhoods in Kufa city. The disparity is largely due to differing indoor air quality, which can be heavily influenced by various factors with a notable impact coming from artificial air fresheners that affect concentrations of specific VOCs in residential settings.

Volatile organic compounds (VOCs) have primary indoor sources contributing to their composition along with certain distinct compounds such as limonene or hexanal: emission sources like ventilation rates coupled with indoor oxidative environment further determine levels of VOCs indoors. Observations show that levels of volatile organic compounds (VOCs) indoors are typically higher than those outdoors; elevated benzene concentrations in colder seasons can be attributed to reduced ventilation as well as the use of oil and gas heaters leading to increased VOC emissions ^[10]. On another note, indoor levels of formaldehyde, toluene, and ammonia show significant dependence on temperature variability which points towards a seasonal impact on indoor air quality dynamics ^[11]. Similarly, parameters such as air temperature, relative humidity, and even age of the flat contribute distinctly to indoor formaldehyde levels underlining the intricate interplay of factors governing indoor air quality considerations ^[12]. Our findings exceeded

WHO limits. There are several other factors that play roles in determining these concentrations: household appliances, building characteristics.. etc., suggesting a more holistic addressing indoor air quality management ^[13]. The presence of ventilation is crucial in altering indoor air quality situation through stalling the accumulation of impurities such as CO₂ and VOCs, which can endanger health over time ^[14]. Hence, an investigation and control of the carbon dioxide and VOC sources should be prioritized in residential settings since it fosters better indoor air quality as well as decreasing adverse health risks due to long-term contact with high levels of pollutants ^[15].

Conclusion

In the research, a study was conducted to measure the carbon dioxide concentration of three residential neighborhoods in the city of Kufa. Unfortunately, most of the results obtained in these were higher than the permissible limits set by the World Health Organization.

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