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# Measuring The Concentrations Of Some Gaseous And Particulate Air Pollutants In The Indoor Environment Of Homes / Iraq , A Case Study)

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**Abstract:** *The purpose of the study is to detect the concentration of some gaseous and particulate air pollutants in the indoor air of the city of Kufa. The pollutants include (CO, $CO_2$, $SO_2$, $NO_2$, $PM_{10}$, $PM_{2.5}$). The concentrations of these pollutants were measured from July 2022 to January 2023 at seventeen stations in the city of Kufa. Three sites (houses) were selected from each station, making (51 dwellings). The study showed the role of some climate elements, such as temperature and humidity, as well as the function of the size of the house and the type of building, as well as the role of the house uses, such as cleaning and cooking materials, in influencing the increase in the concentration of air pollutants. The results showed that there was a variation in the levels of concentrations of air pollutants and their variation between July and January. The results showed that the highest concentration of $CO_2$ gas ("934.6PPM) was at site S2 in station 17 during July, and the lowest concentration (419PPM) was at site S2 in station 15. As for CO gas, the highest concentration was (259.6PPM) at site S2 in station 12, and the lowest was (4PPM) at site S1, in station 14. As for $NO_2$ gas, it reached the highest concentration in Station (1) site S3, with a concentration of (0.12PPM) and the lowest concentration (0.06PPM) in Station 13 is at Site S1. As for $SO_2$ gas, the highest concentration was recorded during the summer at Station 5, Site S2, with a concentration of (PPM 0.09). As for suspended particles, the study's results indicated that the rates of $PM_{2.5}$ and $PM_{10}$ increased in July, while they decreased in January. The highest percentage of indoor particles of both types was recorded at station 13 in site S1, and this is due to the different types of household activities that take place inside homes.*

***Keywords: Gaseous , Particulate Air Pollutants, (CO, $CO_2$, $SO_2$, $NO_2$, $PM_{10}$, $PM_{2.5}$)***

## 1.Introduction

Ecosystems are in a state of equilibrium, ensuring the continued existence of their biotic and abiotic components, and even before the second half of the twentieth century, a state of equilibrium between the inputs and outputs of the system (such as gases, water, salt, energy,

waste, and waste of all kinds, etc.), but the increase The enormous population in our current era has led to an increase in the types and quantities of natural and synthetic materials produced by human activities that pollute the environment, leading to a dangerously unbalanced ecosystem, causing many damages to living organisms and human health [1]. With the progress of science, many compounds that are harmful to the environment have emerged. Many important problems have emerged in environmental pollution and various environmental elements such as air, water, and soil resulting from fuel combustion and various industrial activities, including oxides of carbon, nitrogen, and sulfur [2].

Air pollution is the most significant environmental health risk to the world's population, with approximately 7 million premature deaths each year likely directly linked to exposure to polluted outdoor air, and about 92% of the world's population lives in The air quality increases to good categories that represent the appropriate place according to the World Health Organization guidelines. Children under the age of five (98%) inside these places can breathe easily due to the excellent quality of the place. However, indoor air pollution is the main cause of death for children under the age of 15. It kills 600,000 people every year. Global deaths from air pollution cost an estimated $5 trillion in losses worldwide due to premature death. Exposure to air pollution increases the risks of death and cardiovascular and respiratory diseases, while inhaling Short-term pollutants may cause changes in lung function and the cardiovascular system, worsening health conditions and causing diseases such as coronary heart disease. Thus, health and psychological risks drive the need to inform people about potential or expected environmental health impacts [3].

The general idea is that humans are safe from harmful pollutants indoors, but indoor air can be more polluted than outdoor air[4]. According to the Environmental Protection Agency, indoor pollutant concentrations are two to five times higher than outdoor pollutants and in at least some cases, up to 100 times higher than those [6,5]. Sources of indoor air pollution can be outdoor or indoor. External Sources include emissions from factories and transportation, of which the largest contributors are from internal sources. These sources include poor ventilation, relatively high or low humidity, and other activities near the building that can affect the building's fresh air. In addition, human activities such as smoking use of dyes, air fresheners, and detergents can contribute to poor indoor air quality[7]. The types of pollutants affecting the air quality index are generally divided into biological source, chemical, particulate, and aerosol. Fungi, bacteria, pollen, and animal dander are all biological pollutants. Chemical pollutants include emissions from adhesives, cleaning agents, solvents, combustion byproducts, and floor or wall coverings. Particles and aerosols are solids and liquids suspended in the air due to dust, construction, smoking, or combustion[8,9].

## 2.Methodology

The process of detecting air pollutants in the study area relied on first identifying the selected sites using a GPS device, which numbered (51) sites to measure six gases: CO, $NO_2$, $SO_2$, $CO_2$, in addition to measuring particulate matter (PM10, PM2.5) as a result of summer monitoring. In July , another winter in January of2022, and another winter in January 2023, accompanied by measuring some climate elements (temperatures and relative humidity). Some objective matters were also taken into account that were determined after experimental measurements of the sites, namely determining the type of pollutants prevalent to some extent and knowing when the area was affected by this pollutant. The height of the devices when measuring was 1.5 meters, which is the level of human breathing, while the duration of the measurement and taking on-site readings ranged between (5-10) minutes.These pollutants were

measured using different devices, as shown below:

**Advanced Sense Environmental Test Meter 2012. Gray Wolf USA**

It is a modern device that can be used in the laboratory (fixed) and can be carried portable and used in the field, as this device detects (10) gases, in addition to bearing computer specifications. Fine particle measuring device (PM10, PM2.5).

It is a device of Korean origin that is used to detect the masses of particles present in the air within two size ranges ($PM_{10}$, $PM_{2.5}$) in ppm. In addition, it can measure temperature and relative humidity during the measurement process and shows different air quality values, and the button is pressed to switch between modes. It has been changed to several modes ($CO_2$, $PM_{10}$, $PM_{2.5}$). It also contains a timer, as the device timers for five minutes, during which it continues to detect particle concentrations until it stabilizes at a final reading, and this state continues manually, depending on the model.

## 3.Results and Discussion

1. Carbon dioxide ($CO_2$) concentration

The results of measuring $CO_2$ gas concentrations, shown in Table (1), showed that its levels vary spatially and temporally in the air of the study area, as its concentrations in the summer (the month of July) recorded their highest level in the Maitham Al-Tamar neighborhood (the workers' role) in the site (S1) reaching ((S1). ppm 934.6) On the other hand, its lowest concentration was (419.3 ppm) at Site S2 in the Al-Suhailia neighborhood. As for the measurements conducted during the days of January, the highest concentration was recorded at Site S2 in the Al-Muallimeen residential neighborhood, where it was recorded (ppm 829). In contrast, the lowest gas concentration was reached. Carbon dioxide during January at Site S3 in the Askari neighborhood.

Carbon dioxide is one of the IAQ indicators. Indoor air quality can be checked by indoor carbon dioxide concentration. Indoor $CO_2$ concentration results from outdoor $CO_2$ concentration and indoor $CO_2$ concentration (human metabolism produces indoor $CO_2$). While the outdoor carbon dioxide level is not essential from a health standpoint, it provides a building and affects indoor air quality[10]. Outdoor $CO_2$ concentration can vary from 350-400 ppm or more in areas with heavy traffic or industrial activity. This percentage is much higher indoors. Indoor $CO_2$ concentration depends on the number of people inside, occupancy time, amount of outside air brought inside, room area, indoor air pollution with combustion products (smoking, automobiles), and outdoor $CO_2$ concentration [11]. From the results of the current study, carbon dioxide concentrations were high in July at Station 17 in the Maitham Al-Tamar neighborhood, Site S2, in its three locations, and the reason is generally due to low ventilation rates due to the lack of windows as well as the small area of the house. Station 12 at site S2 in the second and third positions in the Al-Judida neighborhood came in second place regarding carbon dioxide concentration. The increased concentration in this station is the increase in the population compared to the area of the house. This study agreed with the study of Cociorva and Iftene [12]. As for the lowest concentrations in July, station 15 in the Al-Suhailia neighborhood reached the lowest concentration of $CO_2$ gas in site S2, followed by station 12 in station S2 in the New neighborhood. The low concentrations in these sites islow concentrations in these sites are low because they were characterized by good ventilation and a low density of residents inside the house, and this agreed. With the study of Chengappa [13]. As for January, $CO_2$ concentrations increased in some locations. This is due to the frequent use of heaters and

lack of ventilation, which increases the concentrations of some gases, including carbon dioxide, as stated in Turunen's study [13].

2. Carbon monoxide gas (CO)

The results of measuring carbon monoxide gas concentrations, shown in Table (1), showed clear spatial and temporal variation in their levels in the air of the study area. They also showed that they were lower during the winter than in the summer. The highest concentration of CO gas was recorded during July at station (12) in Al-Judida neighborhood, location S2, with a concentration of (259.6 ppm), and the lowest concentration reached (PPM2) in the Rashadiya neighborhood. During January, the highest concentration was recorded at station 16 at site S3 (300.9 PPM), and the lowest concentration (4PPM) was recorded at station 14 at site S1.

Carbon monoxide is a colorless, odorless, and tasteless toxic gas that is generated as a byproduct of combustion. Any fuel-burning device, vehicle, tool or other device has the potential to generate hazardous concentrations of carbon monoxide[14]. Concentrations of carbon monoxide in indoor air are much lower than those recommended by national and international organizations. This may be because there are no major sources of carbon dioxide emissions inside the home.[15] The monthly variation results show that three stations recorded the highest values of carbon monoxide concentrations. The 12 station at Site S2 recorded the highest carbon monoxide concentration value during July 2022. This was because the car was left in a garage inside the house with its engine running. Followed by station 5, site S2 in the police district, this increase is due to using a heating device that burns oil as a fuel source during the measurement period. The following stations were also recorded (19, 11, 13, and 17 in site S2), and all of these concentrations are higher than the permissible international and Iraqi limits (30-45PPM). This is due to cooking processes and the

use of charcoal for barbecue purposes at home, as it is known that incomplete combustion of fuel (such as charcoal in this case) is one of the main sources of carbon monoxide pollution [16].

3.Nitrogen dioxide gas ($NO_2$)

The results of measuring $NO_2$ gas concentrations in Table (1) showed that there is a clear difference in concentrations, as concentrations increase during the winter (January), as the concentrations of nitrogen dioxide gas increase with the decrease in temperature. The highest concentrations appeared during July at station (12) at site S2, with a concentration of (0.13 ppm), and the lowest concentration reached (0.09 ppm) at station 8 at site S1, and in measurements recorded in January, the highest concentration reached (0.8 ppm) at station 1 at Site S2 and the lowest concentration (0.06PPM) is at station 13 at site S1.

3. Concentration of sulfur dioxide gas($SO_2$)

It was found that the concentration of the gas in the winter was significantly higher than its concentration in the summer, and some locations had concentrations below the device's detection limits. Its concentrations increased due to the use of winter fuel and wood-burning heaters in some homes, in addition to the increased use of chemical detergents. This applies to the study Jia and Batterman [21].

The results of measuring $SO_2$ gas concentrations in Table (1) showed a clear difference in concentrations, as its concentrations increase during the winter (January), as the concentrations of nitrogen dioxide gas increased with the decrease in temperature. During July, its highest concentration reached station 5 (PPM 0.09) at site S1, and most of the measurements appeared below the device's detection limits for sulfur dioxide gas. In January, station 5, site S2,

recorded the highest concentration (0.07PPM), and most of the measurements appeared below the device's detection limits.

Nitrogen oxides are an important indicator for evaluating air quality and one of five pollutants that have air quality indicators to reduce outdoor air pollution. Nitrogen oxide emissions are linked to acid rain, photochemical smog, and the destruction of the tropospheric ozone layer. In addition, the inhalation of nitrogen oxide by the human body leads to... It leads to the disruption of the alveolar sacs (pulmonary alveoli) and their lung functions, which poses asignificant threat to human health [17]. The highest concentrations of nitrogen dioxide gas were recorded in July measurements, with concentrations ranging between (0.11 - 0.13) ppm. The highest concentrations appeared in station (12) site S2 in the Al-Jadidah neighborhood with a concentration of (0.13) ppm, and station (1) site S3 in the Maysan neighborhood with a concentration of (0.13) ppm. (0.12) ppm, which is higher than the permissible global limits. The increase was because these locations have increased food cooking operations in the kitchen, in addition to some burning operations inside homes and an increase in smoking [19]. During January 2023, the concentrations of nitrogen dioxide gas increased above what they were in July. The increase in these concentrations is the frequent use of heaters during the winter, which is the most important cause of the emission of nitrogen dioxide gas, in addition to the lack of ventilation inside the rooms, and this applies to the study. Ballester [20].

4. Concentrations of particulate pollutants $PM_{10}$, $PM_{2.5}$

The measurement results shown in Table (1) showed variation in $PM_{10}$ rates at the study stations, where concentrations decreased at higher rates in winter than in summer. During July, the highest value (192µg) was recorded at station 13 at site S1, and the lowest concentration was recorded at station 14 at site S1 at a concentration of (30 µg). The highest concentration was in January in station 13, site S1 (136 µg), and the lowest was (23 µg) in station 4, site S2.

Regarding the results of $PM_{2.5}$, the highest concentration during July was at station 13, location S1, with a concentration of (71 µg) in the end, and the lowest concentration was at station 17, location S3, with a concentration of (11 µg). During January, the highest concentration reached (57 µg) at station (10) site S2, while the lowest concentration reached (11 µg) at station (10) site S2.

About 65% of individuals in developed countries spend their day at home, while the young and the elderly spend more than that. Accordingly, indoor air quality and purity are important for human health. The exchange between indoor and outdoor air is a critical element affecting indoor air quality. Particulate matter is one of the most important factors affecting indoor air quality [22]. There are two basic categories of particulate matter, $PM_{10}$ and $PM_{2.5}$ $PM_{10}$ refers to particles that are 10 microns or less in diameter. $PM_{2.5}$ or "fine particulate matter.

**Table (1) Concentrations of some gaseous and particulate air pollutants in the indoor environment at July and January 2022-2023**

| no | station | site | CO2 | | CO | | NO2 | | SO2 | | PM10 | | PM2.5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | July | Jan | July | Jan | July | Jan | July | Jan | July | Jan | July | Jan |
| 1 | maysan | S1 | 644 | 574.3 | 30 | 30.6 | 0.1 | 0.09 | * | 0.03 | 66.6 | 59 | 42 | 21 |
| | | S2 | 574.6 | 558.6 | 23.6 | 21.3 | 0.1 | 0.08 | * | 0.1 | 91 | 80 | 24 | 19 |
| | | S3 | 505 | 484.6 | 7.6 | 7.3 | 0.12 | 0.09 | * | 0 | 91 | 80 | 76.6 | 25.6 |
| 2 | aleaskari | S1 | 538 | 421 | 8 | 8.6 | 0.1 | 0.09 | 0.05 | 0.01 | 74 | 50 | 35 | 22 |
| | | S2 | 527 | 415 | 7.6 | 5.6 | 0.1 | 0.09 | * | 0 | 81 | 62 | 41 | 32 |
| | | S3 | 542 | 412 | 6.6 | 4 | 0.1 | 0.09 | * | 0 | 67 | 58 | 35 | 31.6 |
| 3 | aljamiea | S1 | 585.6 | 475.6 | 18.3 | 11.3 | 0.1 | 0.1 | * | 0.01 | 151 | 96 | 34 | 25 |
| | | S2 | 517 | 490 | 8.6 | 8.6 | 0.1 | 0.1 | * | 0 | 107 | 91.6 | 34 | 40 |
| | | S3 | 525 | 518 | 9 | 10.3 | 0.11 | 0.1 | * | 0.06 | 103.6 | 84.6 | 35 | 36 |
| 4 | almutanabiy | S1 | 530.6 | 556 | 8.6 | 10.6 | 0.1 | 0.1 | * | * | 129 | 41.6 | 19 | 33 |
| | | S2 | 521 | 507.6 | 5.3 | 6.6 | 0.1 | 0.1 | * | * | 48 | 23 | 24 | 35.5 |
| | | S3 | 530.6 | 548 | 28 | 18 | 0.1 | 0.1 | * | * | 53 | 50 | 25 | 26 |
| 5 | alshurta | S1 | 609.6 | 471 | 16.6 | 2.3 | 0.1 | 0.09 | 0.06 | 0.03 | 37 | 30 | 49 | 25 |
| | | S2 | 796 | 829 | 98.3 | 16.6 | 0.1 | 0.1 | 0.09 | 0.07 | 52 | 30 | 41 | 29 |
| | | S3 | 581.6 | 581.6 | 16.3 | 8.6 | 0.1 | 0.09 | 0 | 0 | 105 | 88 | 34 | 22 |
| 6 | kendah1 | S1 | 614.6 | 591 | 42.6 | 43.6 | 0.11 | 0.09 | * | * | 52 | 42 | 28 | 21 |
| | | S2 | 540 | 522 | 6 | 13 | 0.09 | 0.08 | * | * | 55 | 47 | 28 | 21 |
| | | S3 | 636 | 579 | 14 | 12 | 0.1 | 0.09 | * | * | 71 | 63 | 29 | 19 |
| 7 | kendah2 | S1 | 609.6 | 587 | 33.3 | 27 | 0.1 | 0.09 | * | * | 24 | 27 | 29 | 24 |
| | | S2 | 502.6 | 513.6 | 8.3 | 3.6 | 0.1 | 0.1 | * | * | 82 | 82 | 25 | 20 |
| | | S3 | 538 | 531.6 | 5.3 | 3 | 0.1 | 0.09 | * | * | 89 | 82 | 48 | 31 |
| 8 | almuealimin | S1 | 612 | 471 | 27.6 | 11.6 | 0.09 | 0.09 | * | * | 110 | 100 | 51 | 46 |
| | | S2 | 679 | 829 | 18 | 15 | 0.1 | 0.09 | 0.01 | * | 98 | 80 | 46 | 28 |
| | | S3 | 677 | 674 | 19 | 12.6 | 0.1 | 0.09 | * | * | 99 | 89 | 34 | 22 |
| 9 | aljumhuria | S1 | 551.6 | 823.6 | 7.6 | 20 | 0.09 | 0.1 | * | * | 127 | 118 | 66 | 32 |
| | | S2 | 694 | 757.6 | 53 | 15 | 0.09 | 0.1 | * | * | 75 | 64 | 35 | 32 |
| | | S3 | 631 | 737.6 | 7 | 13 | 0.1 | 0.1 | * | * | 82 | 81 | 44 | 26 |
| 10 | alsaray | S1 | 528 | 581.6 | 5 | 12.3 | 0.1 | 0.09 | * | * | 112 | 117 | 52 | 34 |
| | | S2 | 685.6 | 616 | 6 | 9.6 | 0.1 | 0.1 | * | * | 78 | 51 | 48 | 57 |
| | | S3 | 544 | 570 | 9.6 | 7 | 0.09 | 0.09 | * | * | 82 | 73 | 40 | 46 |
| 11 | alrashadia | S1 | 518 | 652 | 2 | 21.6 | 0.09 | 0.1 | 0.08 | 0.04 | 91 | 82 | 54 | 35 |
| | | S2 | 630.6 | 573 | 45.3 | 17.3 | 0.1 | 0.1 | 0.01 | 0.005 | 95 | 89 | 45 | 24 |
| | | S3 | 533.6 | 542 | 3.6 | 14.6 | 0.1 | 0.1 | * | * | 87 | 92 | 34 | 22 |
| 12 | aljudida | S1 | 548.6 | 571 | 14 | 10.6 | 0.1 | 0.09 | 0.03 | 0.015 | 59 | 49 | 49 | 22 |
| | | S2 | 785.3 | 641 | 259.6 | 65 | 0.13 | 0.1 | * | * | 33 | 24 | 54 | 19 |
| | | S3 | 438 | 520 | 10.3 | 8.6 | 0.12 | 0.06 | * | * | 68 | 51 | 56 | 28 |
| 13 | alwaqf | S1 | 519 | 792 | 5 | 30 | 0.11 | 0.06 | 0.02 | 0.02 | 192 | 136 | 71 | 41 |
| | | S2 | 703 | 743 | 65 | 27 | 0.1 | 0.09 | * | * | 99 | 91 | 66 | 23 |
| | | S3 | 583 | 665 | 7.6 | 13.6 | 0.1 | 0.11 | * | * | 69 | 96 | 60 | 29 |
| 14 | alsahla | S1 | 486 | 557 | 5 | 4.3 | 0.09 | 0.07 | * | * | 30 | 25 | 22 | 20 |
| | | S2 | 452 | 518 | 12 | 4.6 | 0.09 | 0.09 | * | * | 46 | 38 | 29 | 22 |
| | | S3 | 522.6 | 524 | 5.6 | 5 | 0.1 | 0.09 | * | * | 37 | 33 | 34 | 25 |
| 15 | alsuhaylia | S1 | 457.6 | 708.6 | 17.3 | 14 | 0.1 | 0.1 | * | * | 46 | 38 | 31 | 27 |
| | | S2 | 419 | 512 | 11 | 5.6 | 0.1 | 0.1 | * | * | 38 | 36 | 25 | 23 |
| | | S3 | 444.6 | 517.6 | 8 | 9.3 | 0.1 | 0.1 | * | * | 45 | 39 | 42 | 29 |
| 16 | alshueara | S1 | 546 | 525.6 | 7 | 5.6 | 0.1 | 0.09 | * | * | 46 | 41 | 39 | 23 |
| | | S2 | 545 | 532 | 7 | 6.6 | 0.1 | 0.11 | * | * | 40 | 24 | 10 | 12 |
| | | S3 | 562.6 | 542 | 6.3 | 7 | 0.1 | 0.11 | * | * | 33 | 24 | 37 | 31 |
| 17 | Dowr alaumaal | S1 | 514 | 593 | 17 | 14 | 0.11 | 0.1 | 0.02 | 0.01 | 50 | 33 | 22 | 21 |
| | | S2 | 934.6 | 636 | 62.3 | 19.3 | 0.1 | 0.1 | 0.01 | * | 45 | 37 | 31 | 19 |
| | | S3 | 613 | 574 | 8.3 | 13.6 | 0.1 | 0.1 | * | * | 61 | 41 | 11 | 11 |

## -Statistical analysis of the relationship between air pollutants and someinternal factors

The statistical data were analyzed using a statistical model based on triple ANOVA and based on the information criterion (AIC), which is the amount of prediction error. Therefore, the best model was chosen to represent the relationship. The model reveals the extent of the influence of external factors on the concentration of gases in the study areas, as three locations (the kitchen, the bedroom, and the guest room) were chosen in each location (house). Table (2) shows statistically significant differences and the effect of house area, temperature, and humidity on carbon dioxide concentration. The results indicate that increasing house size and temperature are associated with an increase in temperature are

associated with increased in temperature and carbon dioxide concentration.

Moreover, the results indicate no statistically significant differences for humidity, temperature, and house size in relation to carbon monoxide. In addition, Table 3 shows that humidity is the only factor that significantly affects the concentration of sulfur dioxide. This indicates that humidity level changes can affect the concentration of this gas in the home relative to the study area. For PM10 and PM2.5 concentration, the analysis indicates that temperature affects PM10 concentration, while house size only affects PM2.5 concentration. These results highlight the main factors affecting the concentration of gases and particles in the study area.

**Table (2) P(Value) values for the statistical model for the extent of the influence of internal factors on pollutants**

| Gages | Home Size | Ta | Hm |
|---|---|---|---|
| $CO_2$ | 0.00615 ** | 2.12e-05 *** | 0.01018 * |
| CO | 0.394 | 0.465 | 0.572 |
| $NO_2$ | 0.8866 | 0.0681 | 0.0785 |
| $SO_2$ | 0.2859 | 0.1191 | 0.0184 * |
| PM10 | 0.156 | 3.69e-08 *** | 0.124 |
| PM2.5 | 0.0177 * | 8.00e-08 *** | 0.0841 |
| PM2.5 | 0.0177 * | 8.00e-08 *** | 0.0841 |

Hm: humidity, Ta: temperature

**4.Conclusion**

Using a statistical model based on triple anova and relying on the information criterion (AIC) to show the relationship between (temperature, relative humidity, and area home) and air pollutants has shown a strong correlation between them.

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