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Assessing Health Impact of Air Pollutants in Hilla city, Iraq

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Abstract

Any substance that alters the natural properties of the atmosphere, whether it be chemical, physical, or biological, is considered an air pollutant. Air pollution can causes health, economic and environmental damages, etc. This study aims to evaluate the health impact of long-term exposure to particulate matter (PM2.5), as this pollutant is the one that governs air quality. Using the AirQ software and based on the data obtained from the Babylon Environment Directorate . The dust storms that occurred in the spring and summer of 2022 contributed to an increase in the $PM_{2.5}$ seasonal concentration to 84 µg/m^3. The long-term exposure was evaluated to the pollutant, which causes the following diseases: (Lung cancer , Acute Lower Respiratory Disease , Chronic Obstructive Pulmonary, Ischemic Heart Disease, and stroke). The results showed that the relative risk increased to 1.376 for lung cancer, 1.534 for ALRI, 1.412 for COPD, 1.399 for IHD, and 1,367 for stroke, the highest risk was recorded for ALRI because children are more susceptible to disease than others. The air quality was moderate at a rate of 45% to unhealthy for sensitive groups at a rate of 31% in 2022 and good at a rate of 28% to moderate at a rate of 45% in 2021.

Key words: AirQ , Air Pollution , PM2.5 , Long term exposure.

1. Introduction

Compounds that make up ambient (outside) air pollution are complicated mixtures, and their concentrations fluctuate according to their sources, location, topography, wind speed and direction, temperature, UV radiation, and relative humidity. Due to the fact that they originate from the same sources and are dispersed similarly, the concentrations of pollutants can be connected both in time and location. Particles are frequently categorized based on size, and this provides information regarding potential health impacts [1].

Particulates and gaseous pollutants make up ambient urban air pollution (PM). Ozone (O3), volatile organic compounds (VOCs), carbon monoxide (CO), and nitrogen oxides (NOx), which are all well-known as inflammatory stimuli on the respiratory system, are part of the former[2].

After inhalation, the respiratory system is the main site of exposure to air pollution. The primary interface between the immune system and the airborne environment is the respiratory tract, which extends from the nasal passages via the airways to the alveolar gas exchange units in the lungs[2].

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Despite the fact that the majority of current epidemiological research has been on the consequences of short-term exposures, a number of studies indicate that long-term exposure may be more significant in terms of overall public health[3].

If chronic exposure to ambient air pollution poses a substantial risk to health in western developed nations, this issue is far more severe in emerging nations, where population growth, extensive industrialisation, and urbanization have led to the development of crowded, polluted metropolitan centers[4].

Air pollution is a significant yet underappreciated source of non-communicable diseases, which account for 70% of air pollution deaths [5]. In 2015, air pollution caused 24% of ischemic heart disease fatalities, 21% of stroke deaths, 21% of lung cancer deaths, and 19% of total cardiovascular deaths globally[6]. Moreover, ambient air pollution seems to be a significant, albeit not yet measured risk factor for neurodegenerative diseases in adults and neurodevelopmental disorders in children[7].

One in eight premature deaths globally are caused by exposure to air pollution, proving that it is currently the biggest environmental health concern in the world. Almost half of air pollution-related deaths, the majority of which occur in Asia, are caused by PM2.5. Moreover, export-related production is frequently to blame for the premature death from PM2.5 pollution. In one area, PM2.5 primary and precursor emissions have an impact on local aerosol pollution and are enhanced by atmospheric pollution transport, which may come from remote areas[8].

Both PM10 and PM2.5 have varied chemical compositions and frequently come from various sources of emissions. Most of the PM2.5 pollution in outdoor air is caused by emissions from burning gasoline, oil, diesel fuel, or wood. PMs can either be directly emitted from sources (primary particles) or formed in the atmosphere by chemical reactions between gases (secondary particles), like sulfur dioxide (SO_2), nitrogen oxides (NO_X), and specific organic compounds[9].

Abbas et al. also evaluated the impact of long-term exposure in five Iraqi cities(Al-Najaf, Al-Muthanna, Maysan, Kirkuk and Baghdad) and obtained that Baghdad has the greatest rate of mortality by lung cancer(LC) as a result of exposure to PM2.5 among the cities under consideration. The relative risk of mortality due to lung cancer for Baghdad is 1.25 (95% CI: 1.14–1.4). Nonetheless, Maysan had the lowest relative risk, with an relative risk of mortality due to lung cancer of 1.2 (95% CI: 1.11–1.32) [10].In the same way, we will evaluate the health impact of exposure to air pollution in the city of Hilla using the AirQ$^+$, when the dust storms that occurred in 2022 increased the concentrations of particles matter (PM2.5) in the atmosphere

2. Material and Methods

2.1 Study Area

Hilla city occupies the northern part of the Babylon which is one of the central Iraqi provinces. Geographically, the city is between Najaf and Baghdad province. It is precisely located on 44.43 longitude and 32.48 latitudes coordinates with a desert climate characterized by low rainfall and high summer temperatures as high as 50 ^oC. The population of the city is 628,861 and 645,016 for the years 2021 and 2022, respectively. The region has many sand dunes, which contributes to the formation of dust storms, as well as the increase in area that have undergone desertification and the decline of agricultural lands, both of which are reflected on the environmental aspect. The soil is, therefore, considered one of the important

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natural parts because of its significant and obvious impact on weather manifestations, particularly on the phenomenon of the formation of dust storms.

2.2 Data

Three air quality monitoring stations in Hilla have been used to collect the daily mean concentration of PM2.5 for a period of time extending from January 2021 to January 2023. The first station is located in Babylon University while the others are in the Hilla textile factory in the Nader neighborhood, and in Abu Khastawi. All stations belong to Babylon Environment Directorate. For a fair measurement, the arithmetic average of the recorded data from the three stations was taken and used as input parameters in AirQ$^+$ software .
Samples were collected using beta attenuation mass device (BMA 1020, MetOne Instruments Inc., Grants Pass, OR, USA) and it is shown in Fig.1. The device contains a tiny carbon-14 element that emits beta rays continuously through a filter tape. A vacuum pump loads ambient PM2.5 onto the filter tape by allowing a regulated amount of air to pass through it. The mass of PM2.5 on the filter tape is identified using the attenuation of the beta ray signal, and the volumetric concentration in the surrounding air is computed. To meet the US EPA Federal Equivalent Method designation for continuous PM2.5 monitoring, specific settings and accessories were used. These are 42 minutes of active sampling phase (from time xx:08 to time xx:50 per hour). This is followed by 18 minutes of tape movement and filter tape reading before and after the sampling period. This measuring preducture is reported in details in the work of [11].

Figure 1. BMA 1020 Device

2.3 AirQ$^+$ Software

The World Health Organization (WHO) and the European Center for Environment and Health (ECEH) jointly recommended the AirQ+ program for this investigation. This software is made to examine the effects of air pollution on human health over a specific period of time and area. The AirQ+ model bases all of its computations on concentration-response functions and techniques derived from epidemiological studies [12]. According to the baseline incidence of health outcomes, cut-off values of desired concentration, and relative risk (RR), AirQ+ calculates the proportion of cases in a range of air pollutants concentration, the attributable proportion, and the attributable cases per 100,000 population at risk[13].

2.3.1 Relative Risk (RR)

This parameter is defined as the chance of an event to be happened in an exposed population group divided by the probability of an event that can happen in a non-exposed group. This

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parameter helps determining directly the relationship between exposure and illness. A log-linear formula is commonly used to model the relative risks parameter to a pollution in air and this relation is as follows:

$$\mathbf{RR = exp^{\beta(X-X_0)}} \quad (1)$$

where Xo is the cut-off or counterfactual such as the background concentration or the lowest feasible value and X is the contaminant concentration (in µg/m^3). ß represents the change in the RR that is equivalent to a one-unit change in the contaminant concentration (WHO, 2018) [14].

2.3.2 Attributable Proportion (AP)

AP is the proportion of the population at a given level of exposure. In other words, it means the part of the infection rate that can be reduced if the source of exposure is eliminated and that is related to the quantification of health effects WHO, 2018).

The percentage of health that can be assigned to exposure in a given population for a specific period can be calculated using Eq.2 developed by Krzyzanowski (1997). The equation is based on assuming that there is a causal relationship between exposure and health result and that there are no substantial confounding factors:

$$\mathbf{AP = SUM \frac{\{[RR(C)-1]*P(C)\}}{SUM[RR(C)*P(C)]}} \quad (2)$$

where RR , as defined previously, is the relative risk of an exposed group (here is named group C), P(c) stands for the exposed group C population ratio.

2.3.3 Incidence of Exposure (IE)

The quantity attributable to population exposure can be determined using the baseline incidence of the chosen health results and will be computed as follows:

$$\mathbf{IE=I*AP} \quad \mathbf{(3)}$$

where I is the population-wide baseline incidence of the health result.

2.3.4 Quantity of Cases Attributed to Exposure (NE)

The last parameter can be computed is the quantity of cases attributed to exposure and that parameter can be estimated as a function of the number of population (N) [15].

$$\mathbf{NE=IE*N} \quad \mathbf{(4)}$$

Where NE is the number of cases attributable to exposure and N is the size of the population studied.

3. Results and Discussion

3.1 $PM_{2.5}$ Concentrations

The average values of PM2.5 daily concentration for Hilla city in 2021 and 2022, respectively shown in Figure 2. Looking closely at the results, it is clear that the concentrations has exceeded Iraqi air quality standards (i.e. 25 µg/m^3, 24-hour mean, and 10 µg/m^3 annual mean) in many days. Comparing the concentrations values in the these sequent years, one can find that the lowest concentration is 3.22 µg/m^3 and the highest is 185 µg/m^3 in 2021, while in 2022 the corresponding values are 16.8 and 674 µg/m^3, respectively. It is important to note here that the highest value in 2022 represents a dust storm day. These results reveal that pm2.5 is consistently high, indicating to a series air pollution occurred in Hilla city during 2022. As discussed previously, this can have detrimental implications on the health of the citizens since high levels of PM2.5 can contribute to respiratory problems and even lung cancer for the long term exposure. Moreover, the environmental impact of air pollution is also significant and can lead to consequences such as acid rain and the

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eutrophication of water bodies. Therefore, it is crucial to undertake measures to control and reduce air pollution levels in the city.

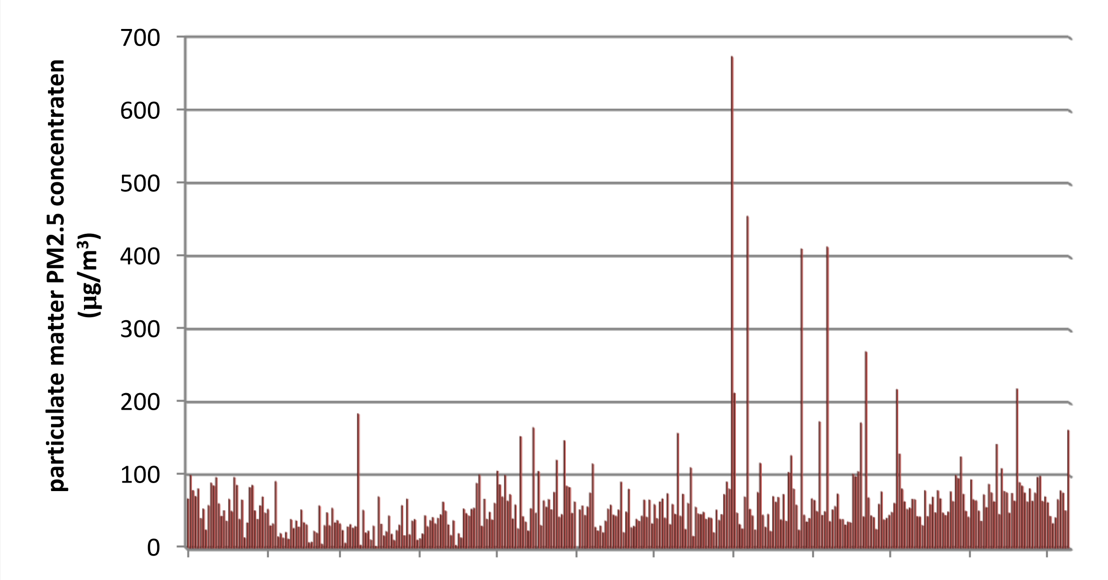

Figure 2. Particulate Matter (PM2.5) Daily Mean Concentration in (μg/m^3)for 2021-2022

Air Quality Index provides information on air quality and the amount of basic pollutants in it, so that the air quality index is calculated according to the concentrations of pm2.5 in the current study. To evaluate the air quality at pm2.5, the Indian specifications are taken as a reference because they are closer to the Iraqi standards and the standards of the WHO. Table 1 shows Air Quality Index for PM2.5 Parameter and there exposure limits during 2021-2022

Table 1. Air Quality Index for PM2.5 Parameter and Their Safe Exposure Limits

AQI	Color	PM2.5(μg/m^3)	2021	2022
Good	Green	0-30	28%	8%
Moderate	Yellow	31-60	45%	45%
Unhealthy for sensitive groups	Orange	61-90	19%	31%
Unhealthy	Red	91-120	5%	8%
Very unhealthy	Violet	121-250	3%	6%
Hazardous	Dark red or brown	+250	0%	2%

It is clear from the table that air quality index is moderate (see Table 1) until it reaches 19% where it is considered unhealthy for sensitive groups. Lower than that (i.e. 5%) is also unhealthy but it not hazardous because of the absence of dust storms during 2021 and the weather was clearer comparing to that in 2022. Table 1 shows that 2% is hazardous and 6% is very unhealthy which are the days of dust storms where the concentrations ranged approximately from 200 to 700 μg/m^3. The air quality for pm2.5 this year is considered to be moderate, with a rate of 45% to be unhealthy for the sensitive group. Further, the air quality

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in 2021 was better than that in 2022, as it was characterized by normal rates of rain and humidity, which contributed to the absence of the problem of dust storms and that appeared significantly in 2022.
Using the Excel program by applying the arithmetic average of the daily concentrations of pm2.5, the seasonal concentration was obtained, which will be used in the research, as shown in the Table2.

Table 2. Concentrations of Air Pollutants During 2021 and 2022

PM2.5 C (μg/m^3)	2021	2022
Minimum	3.22	16.81
Maximum	185.44	674.48
Winter	58	57
Spring	29	84
Summer	29	84
Autumn	70	73

3.2 Impact Assessment for Long Term Exposure

The term "long-term exposure" (sometimes known as "chronic exposure") refers to prolonged, continuous, or recurrent contact with a pollutant (months or years). This pollutant damages people's health over time as it builds up in the reign. We will evaluate the effects on health using seasonal PM2.5 concentration.
Lung cancer (LC), acute lower respiratory illness (ALRI), chronic obstructive pulmonary disease (COPD), ischemic heart disease (IHD), and stroke are among the health impacts of long-term exposure to PM2.5.
According to the Iraqi and the World Health Organization(WHO) standard for air pollution of pm2.5(10 μg/m^3 annual or seasonal mean), when the concentration is within the standard specifications, the relative risk is R = 1. If the relative risk is equal to one, the long-term exposure to the pollutant does not affect human health and attributable proportion(AP) equal to zero.

3.2.1 Relative Risk (RR)

1. Winter 2021-2022

The winter concentration in the first year was 58 μg/m^3, which is close to 57 μg/m^3 in the second year. Increasing the concentration contributed to an increased relative risk of mortality due to exposure to PM2.5 . The relative risk of lung cancer was recorded in the first year more than the second, as it reached 1.263 in 2021 and 1.258 in 2022, which is very close , as shown in Figure (3)&(4). The highest relative risk was recorded for ALIR, reaching 1.387 in 2021 and 1.381 in 2022, because children are more vulnerable to harm than others due to low immunity. The relative risk of COPD and IHD is close, reaching 1.3 and 1.311, respectively in the first year, and 1.296 and 1.307, respectively in the second year.

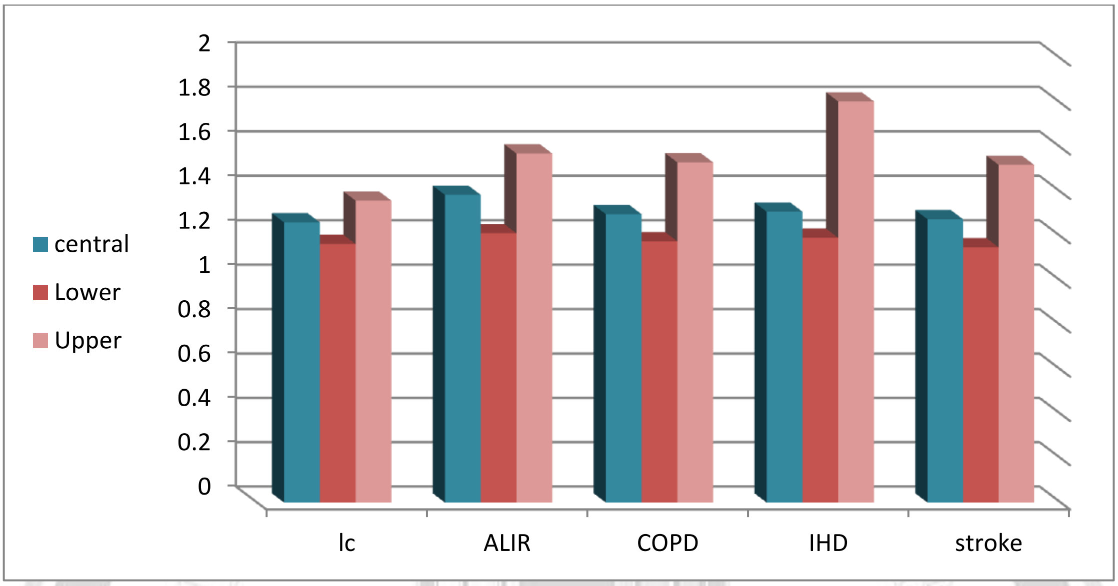

Figure 3. Relative Risk Of Mortality Due To Long-Term Exposure During Winter 2021

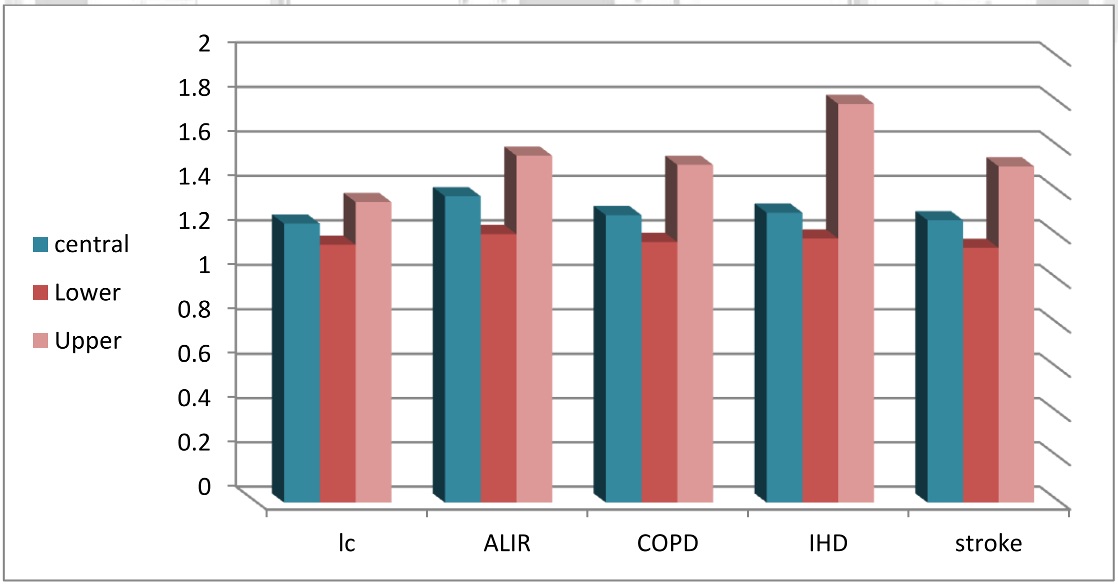

Figure 4. Relative Risk Of Mortality Due To Long-Term Exposure During Winter 2022

2. Spring 2021-2022

Dust storms that occurred frequently in 2022, along with the lack of rain this year, contributed to an increase in the seasonal concentration to 84 µg/m^3. Increasing the concentration contributed to increasing the relative risk, reaching 1.376 for lung cancer, 1.534 for ALIR, 1.412 for COPD, 1.399 for IHD, and 1.367 for stroke, as shown in figure(6). While 2021 was characterized by good precipitation rates with a lack of human activities, as it contributed to decreasing the seasonal concentration to 29 µg/m^3. However, the relative risk increased to 1.119 for lung cancer, 1.18 for ALIR, 1.148 for COPD, 1.171 for IHD, and 1.144 for stroke, as shown in figure(5)

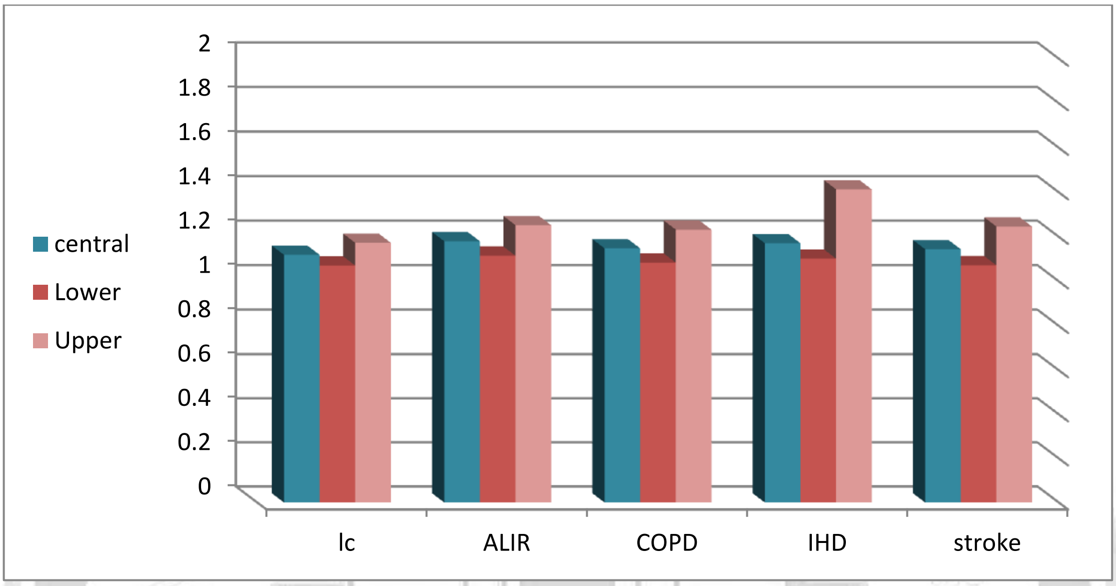

Figure 5. Relative Risk Of Mortality Due To Long-Term Exposure During Spring 2021

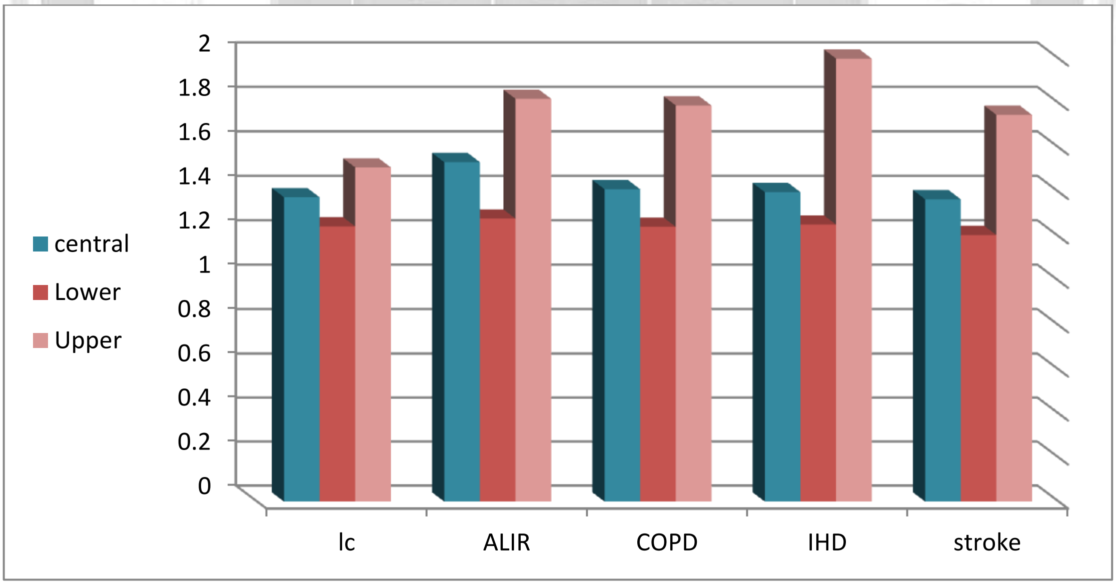

Figure 6. Relative Risk Of Mortality Due To Long-Term Exposure During Spring 2022

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3. Summer 2021-2022

Dust storms that occurred frequently in 2022, along with the lack of rain this year, contributed to an increase in the seasonal concentration to 84 μg/m^3. Increasing the concentration contributed to increasing the relative risk, reaching 1.376 for lung cancer, 1.534 for ALIR, 1.412 for COPD, 1.399 for IHD, and 1.367 for stroke, as shown in figure(8). While 2021 was characterized by good precipitation rates with a lack of human activities, as it contributed to decreasing the seasonal concentration to 29 μg/m^3. However, the relative risk increased to 1.119 for lung cancer, 1.18 for ALIR, 1.148 for COPD, 1.171 for IHD, and 1.144 for stroke, as shown in figure(7).

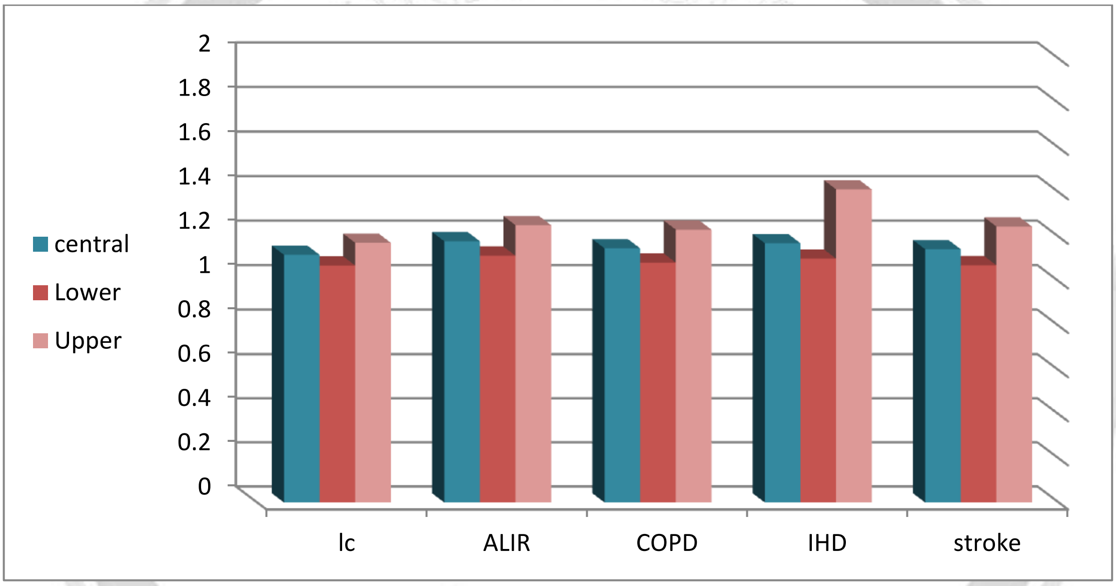

Figure 7. Relative Risk Of Mortality Due To Long-Term Exposure During Summer 2021

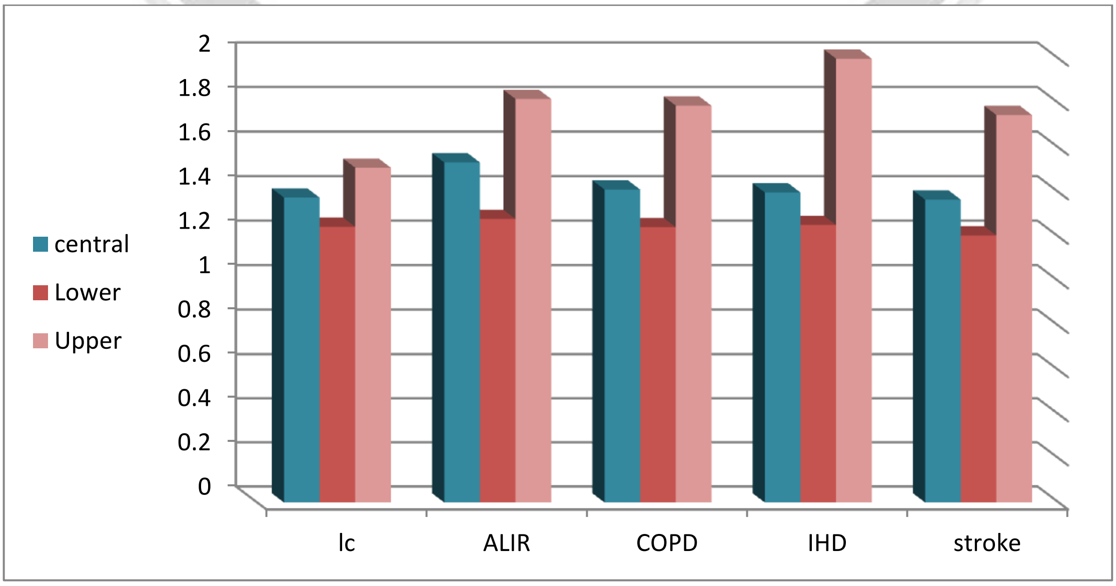

Figure 8. Relative Risk Of Mortality Due To Long-Term Exposure During Summer 2022

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4. Autumn 2021-2022

The autumn concentration in the first year was 70 µg/m3, which is close to 73 µg/m^3 in the second year. Increasing the concentration contributed to an increased relative risk of mortality due to exposure to PM2.5 . The relative risk of lung cancer was recorded in the first year it reached 1.316 in 2021 and 1.329 in 2022, which is very close , as shown in figure (9)&(10). The highest relative risk was recorded for ALIR, reaching 1.459 in 2021 and 1.475 in 2022, because children are more vulnerable to harm than others due to low immunity. The relative risk of COPD and IHD is close, reaching 1.354 and 1. 354, respectively in the first year, and 1.367 and 1.364, respectively in the second year.

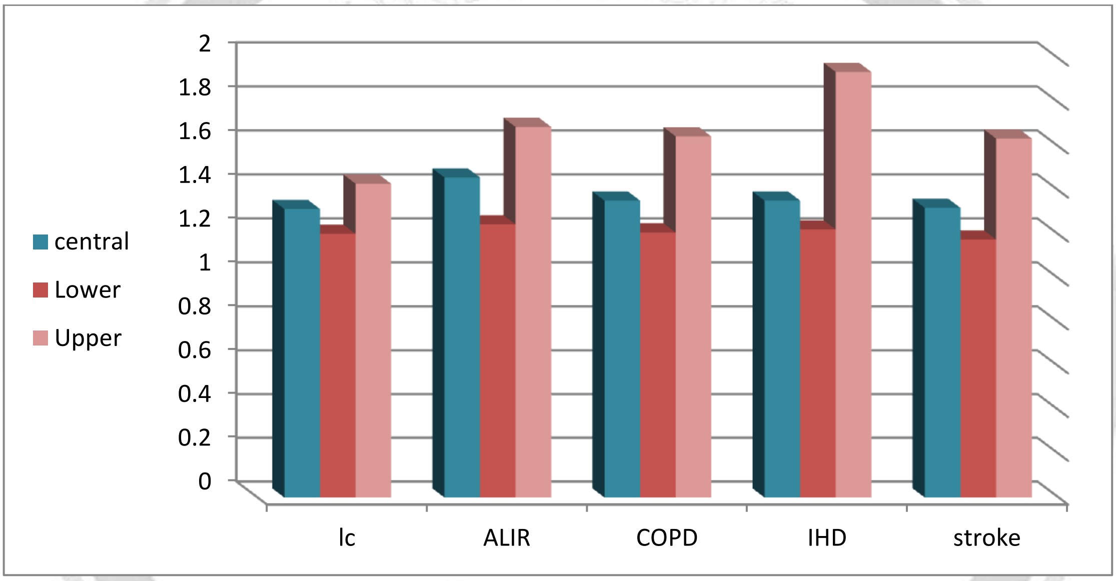

Figure 9. Relative Risk Of Mortality Due To Long-Term Exposure During Autumn 2021

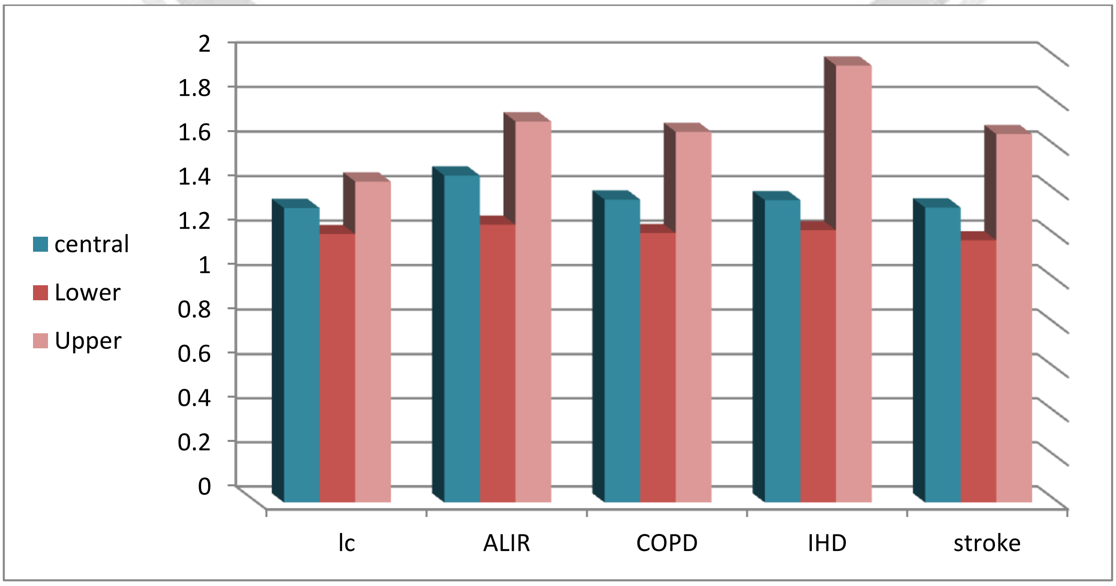

Figure 10. Relative Risk Of Mortality Due To Long-Term Exposure During Autumn 2022

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3.2.2 Attributable Proportion (AP)

AP is the proportion of the population at a given level of exposure. The attributable proportion increases with the increase in the relative risk of the disease, and as mentioned previously, the highest relative risk we obtained is for ALIR, and therefore the attributable proportion is higher, as shown in Table .The attributable proportion for lung cancer (AP_1), which does not exceed 24% for the year 2021. The least effect in the spring and summer season for 2021 was 10.62%, while the effect for the same two seasons for 2022 was 27.32%.The attributable proportion for ALIR (AP_2). The least effect in the spring and summer season for 2021 was 15.27%, while the effect for the same two seasons for 2022 was 34.82%. The attributable proportion for COPD(AP_3). The least effect in the spring and summer season for 2021 was 12.88%, while the effect for the same two seasons for 2022 was 29.19% . The attributable proportion for IHD(AP_4). The least effect in the spring and summer season for 2021 was 14.62%, while the effect for the same two seasons for 2022 was 28.5% . The attributable proportion for stroke (AP_5). The least effect in the spring and summer season for 2021 was 12.6%, while the effect for the same two seasons for 2022 was 26.85%.

Table 3. Attributable Proportion For Long-term Exposure to $PM_{2.5}$

Season	Concentration $\mu g/m^3$	AP1	AP2	AP3	AP4	AP5
Winter 2021	58	20.80%	27.89%	23.11%	23.72%	21.68%
Spring 2021	29	10.62%	15.27%	12.88%	14.62%	12.60%
Summer2021	29	10.62%	15.27%	12.88%	14.62%	12.60%
Autumn2021	70	24.02%	31.44%	26.15%	26.16%	24.28%
Winter 2022	57	20.51%	27.56%	22.83%	23.49%	21.44%
Spring 2022	84	27.32%	34.82%	29.19%	28.50%	26.85%
Summer2022	84	27.32%	34.82%	29.19%	28.50%	26.85%
Autumn2022	73	24.77%	32.23%	26.84%	26.70%	24.87%

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Using the SPSS program, linear regressions were created for the relationship of the number of cases for each disease of long-term exposure with the concentration of dust particles in eight seasons during the two years of research. All models gave a high R^2 value the model gives a strong evaluation if the $R \geq 0.8$. It is clear that the model gives a good estimation , as shown in Table 4. The highest square root obtained is for lung cancer 0.9909, as it is one of the most common diseases and remains one of the leading causes of death worldwide.

Table4. The Number Of Cases Resulting From Exposure to $PM_{2.5}$ Concentrations During Eight Seasons for 2021-2022

Diseases	Models	R^2
Lung cancer	Y=3.0762 X+21.447	0.9909
Acute Lower Respiratory Disease (ALRI)	Y=3.6168 X+55.4	0.9819
Chronic Obstructive Pulmonary(COPD)	Y=3.0095 X+46.838	0.9869
Ischemic Heart Disease (IHD)	Y=2.5684 X+77.564	0.979
Stroke	Y=2.632 X+54.796	0.9843

Conclusion

1. Long-term exposure causes death as a result of the following diseases : (lung cancer, acute lower respiratory disease, chronic obstructive pulmonary, ischemic heart disease, and stroke).

2. The air quality was moderate at a rate of 45% to unhealthy for sensitive groups at a rate of 31% in 2022 and good at a rate of 28% to moderate at a rate of 45% in 2021.

3. The dust storms contributed to an increase in the seasonal concentration during the summer and spring of 2022, and thus to an increase in the relative risk of long-term exposure diseases. The relative risk increased to 1.376 for lung cancer, 1.534 for ALRI, 1.412 for COPD, 1.399 for IHD, and 1.367 for stroke.

4. Although lung cancer is the most common disease, it has a lower risk than others .

5. The models show a good statistical relationship, as the increase in the number of cases is closely related to the increase in concentration. The highest R^2 obtained is for lung cancer 0.9909.

6. By lowering the burden of disease linked to air pollution and assisting in the short and long-term mitigation of climate change, policies to reduce air pollution offer a win-win strategy for both climate and health.

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تقييم الاثر الصحي لتلوث الهواء في مدينة الحلة ، العراق

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الخلاصة

أي مادة تغير الخواص الطبيعية للغلاف الجوي سواء كانت كيميائية أو فيزيائية أو بيولوجية تعتبر ملوثًا للهواء. يمكن أن يتسبب تلوث الهواء في أضرار صحية واقتصادية وبيئية ، وما إلى ذلك. تهدف هذه الدراسة إلى تقييم الأثر الصحي للتعرض طويل الأمد لمادةPM2.5 ، حيث أن هذا الملوث هو الذي يتحكم في جودة الهواء. استخدام برنامج AirQوبناءً على البيانات التي تم الحصول عليها من مديرية بيئة بابل. ساهمت العواصف الترابية التي حدثت في ربيع وصيف عام 2022 في زيادة تركيز PM2.5 الموسمي إلى 84 ميكروغرام / م^3. تم تقييم التعرض طويل الأمد للملوثات التي تسبب الأمراض التالية: (سرطان الرئة ، أمراض الجهاز التنفسي السفلي الحاد ، الانسداد الرئوي المزمن ، أمراض القلب الإقفارية ، والسكتة الدماغية). أظهرت النتائج أن الخطر النسبي ارتفع إلى 1.376 لسرطان الرئة ، 1.534 لـ أمراض الجهاز التنفسي السفلي الحاد ، 1.412 لمرض الانسداد الرئوي المزمن ، 1.399 لـ أمراض القلب الإقفارية ، و 1.367 للسكتة الدماغية ، تم تسجيل أعلى خطر لـ أمراض الجهاز التنفسي السفلي الحاد لأن الأطفال أكثر عرضة للإصابة بالمرض من غيرهم. كانت جودة الهواء معتدلة بمعدل 45٪ إلى غير صحية للمجموعات الحساسة بمعدل 31٪ عام 2022 وجيدة بمعدل 28٪ إلى معتدلة بمعدل 45٪ عام 2021.

الكلمات الدالة: برنامج AirQ, تلرث الهواء, برنامج PM2.5, تعرض طويل الامد.

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