Investigating air pollution and its relationship to geographic and demographic data in Karbala

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Abstract

The purpose of conducting this study in the city of Karbala, specifically on the day of the Arbaeen visit, is to determine the effect of increasing the concentrations of polluting gases on the health of visitors to the city . This study investigates the changes in the levels of ozone (O3), sulfur dioxide (SO2), and carbon monoxide (CO) over the city of Karbala. These gases are considered among the gases that are believed to threaten human health and cause suffocation and other problems resulting from the increase in their concentration. The Sentinel-5 tropospheric monitoring instrument (Sentinel-5P TROPOMI) was used to find SO2, O3 and CO to monitor local air quality and pollution using relatively high-resolution satellite data and to investigate the relationship between the pollutants and the demographic and geographic information of the study area. Geospatial analyzes were performed using demographics data and numerical elevation models and vegetation cover for this purpose . The results showed that the district of Al-Hur showed a greater increase in the concentration of carbon dioxide gas compared to other regions, while the amount of ozone gas increased in the center of Karbala region, especially near the road used by tourists traveling from Najaf to Imam. The shrine, while the increase in sulfur dioxide is distributed in each of the districts of AlHusseinah, Al-Hur and the western strip. The overall conclusions of the study showed that local air quality and pollution levels can be monitored using Sentinel-5P TROPOMI dataSentinel-5P TROPOMI

Keywords: Sentinel 5 , Air Quality , Arbaeen Visit , Tropomi , Air Pollution , Visitor Road. Sentinel-5p Tropomi.

Semi-Annual Scientific Journal www.arbnj.com Shaaban 1445 A.H, March 2024 A.D

1. Introduction

The problem of air pollution is getting worse as the world's population is growing so quickly. Urbanization, energy use, transportation, and motorization are some of the major contributors to air pollution. Additionally, the environment's quality and people's health are negatively impacted by population increase and exposure to air pollutants [1]. Using satellite-based equipment, the atmosphere's concentration of SO2, O3, and CO can be determined. TROPOMI (TROPOspheric Monitoring Instrument), the only payload on board the Sentinel-5 Precursor (S5P) satellite of the European Space Agency (ESA), was launched in October 2017. Due to its unprecedented spatial resolution (3.5 7 km at the beginning of the mission and 3.5 5.5 km since 6 August 2019) and high signal-to-noise ratio, TROPOMI is expected to revolutionize the way we monitor air pollution from space [2]. At the same time, recent years have seen a significant expansion in the possibilities for remote observations of the status of the atmosphere. Particularly, several satellites have been put into orbit above the Earth with the primary objective of detecting the vertical distribution of several atmospheric chemicals, such as ozone, nitrogen dioxide, methane, carbon monoxide, water vapor, and aerosols[3]. Another gas released by the coal mining industry is CO. CO is a key component in the creation of ground-level ozone (O3) and has a brief atmospheric lifespan (days to a few weeks). In the atmosphere, CO and OH interact and lower each other's concentrations. Meanwhile, powerful greenhouse gases like methane have a shorter lifetime because to OH radicals. As a result, the decrease in (OH) enhances the indirect global warming potential of these gases [5].

2. Study area:

The study area is located within Karbala city , as it includes all of the sub-districts of Al-Husayniyyah and part of Al-Hur sub-district within the Karbala district, and the sub-districts of Al-Khairat and Al-Jaddol Al-Gharbi within the Al-Hindiyah district, in addition to the center of the Karbala district, with an area of approximately (1491.048) km2, as it lies between (43.93 - 44.48) longitudes, and latitudes (32.18 - 32.96). As it passes through the study area three of the main roads used by visitors heading to visit the Arbaeen, so it was necessary to study the air quality within the study area . As for the spatial boundaries of the study, the data were taken on September 17, 2022.

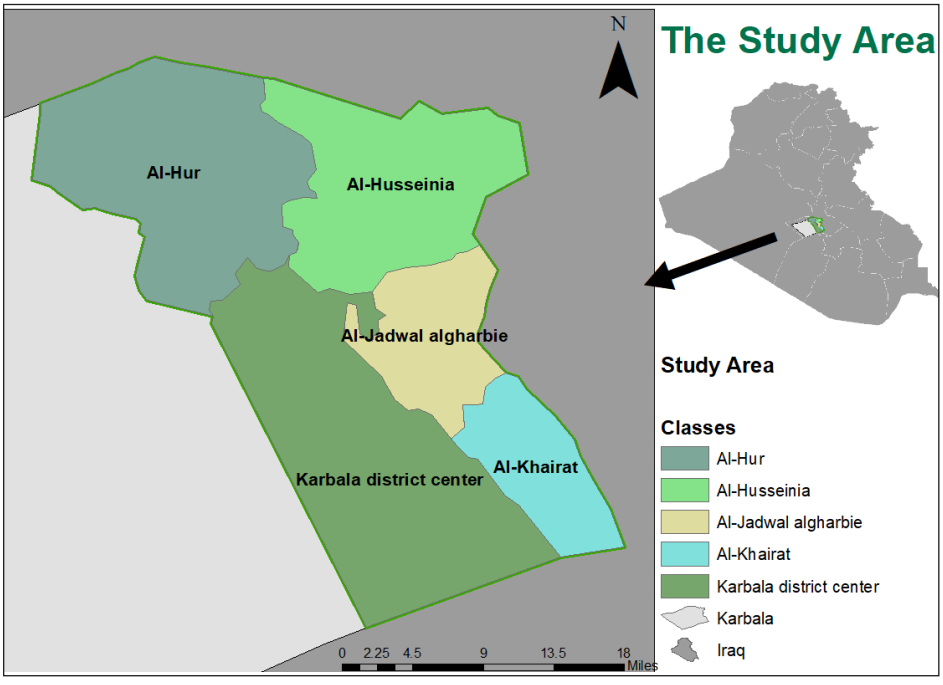

Figure (1) :Represent the study area

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3. Data and Methods:

The single payload of the Sentinel-5p spacecraft, which was launched into low-Earth orbit on October 13, 2017, is TROPOMI, a space-borne spectrometer that covers wavelength bands between the ultraviolet and the shortwave infrared. It was funded jointly by the Netherlands Space Office and the European Space Agency (ESA). The information is freely available for download via the ESA Copernicus Open Access Hub. [1] The data used in this study from the Sentinel 5 satellite are satellite images that have been processed and corrected by Q GIs and Arc Map software as they provide information on the concentrations of carbon monoxide, sulfur dioxide and ozone gas. The study area passes through three of the main roads that visitors use to travel from the city limits of Karbala to the shrine of the two Imam.

Several stations distributed along the three roads were chosen to measure the concentration of gases at each station, using spatial analysis tools from Arc Map software to study the distribution and identify areas of high concentration and areas of low concentration, as shown in Table (1). which shows the location of each station and the concentration of those gases in each station.

Table (1) the concentration of gases on stations

Stations	longitude	latitude	SO2 mol/m2	O3 mol/ m2	CO mol/ m2
0	44° 2' 19.444" E	32° 37' 16.632" N	-2.6E-05	0.127139	0.034329
1	44° 2' 41.379" E	32° 38' 6.384" N	-0.00056	0.12678	0.034329
2	44° 3' 11.892" E	32° 39' 7.017" N	0.000506	0.125964	0.034329
3	44° 4' 15.096" E	32° 40' 6.714" N	0.000506	0.125964	0.032866
4	44° 5' 7.044" E	32° 41' 0.030" N	0.000506	0.125964	0.032866
5	44° 7' 2.002" E	32° 41' 25.231" N	0.000506	0.125964	0.032866
6	44° 2' 7.822" E	32° 36' 48.351" N	-2.6E-05	0.127139	0.034329
7	44° 3' 27.676" E	32° 36' 21.693" N	-0.00056	0.12678	0.034329
8	44° 6' 47.608" E	32° 35' 57.537" N	-0.00056	0.12678	0.034329
9	44° 8' 37.191" E	32° 35' 13.637" N	0.000329	0.127027	0.034425
10	44° 11' 59.306" E	32° 34' 23.293" N	-1.8E-05	0.127829	0.031757
11	44° 12' 51.884" E	32° 32' 39.966" N	0.000436	0.12822	0.031757
12	44° 16' 1.408" E	32° 32' 36.753" N	0.000436	0.12822	0.031757
13	44° 18' 29.708" E	32° 32' 24.831" N	-7.7E-05	0.127302	0.031757
14	44° 20' 37.038" E	32° 32' 9.351" N	-7.7E-05	0.127302	0.032769
15	44° 1' 51.012" E	32° 35' 40.533" N	-2.6E-05	0.127139	0.034425
16	44° 3' 16.093" E	32° 34' 5.764" N	-0.00071	0.127566	0.034425

17	44° 6' 59.052" E	32° 31' 24.774" N	-0.00071	0.127566	0.033514
18	44° 8' 23.886" E	32° 29' 46.905" N	0.000365	0.127101	0.033514
19	44° 9' 56.021" E	32° 27' 22.140" N	0.000365	0.127101	0.034239
20	44° 11' 8.912" E	32° 25' 28.427" N	-0.00032	0.127942	0.033652
21	44° 13' 12.082" E	32° 22' 39.404" N	0.000626	0.128382	0.031459
22	44° 15' 8.735" E	32° 20' 10.874" N	0.000626	0.128382	0.032276

4. Result and discussion

4.1. NDVI and UHI of study area

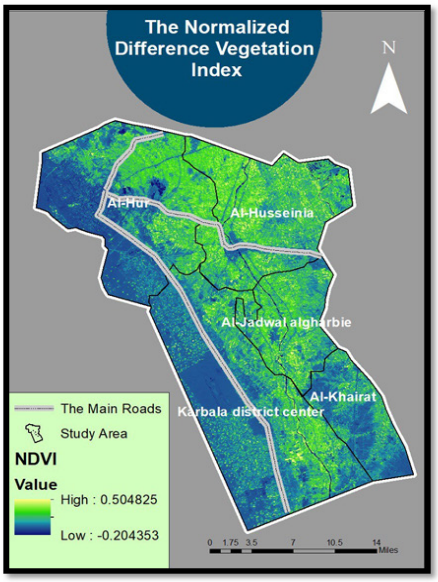

Figure (2) the ndvi of study area

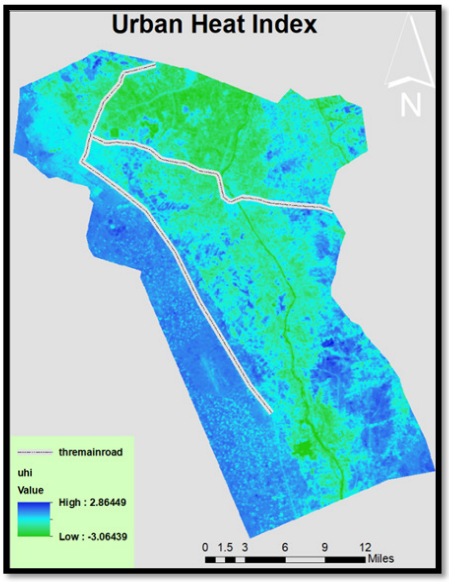

Figure (3) the uhi of study area

4.2. Carbon monoxide (CO) :

CO is an odorless and colorless gas that may emit from incomplete incineration of any carbonaceous materials. The major source of CO are tobacco smoke, gas stove and pilot lights, wood stove and fire places, usage of kerosene fuelled vehicles and gasoline engines In general, movement of automobiles are the most productive source of CO concentration in air [6] . Figures (4, 5) show the distribution intensity of carbon monoxide gas within the study area, as well as the distribution along the three roads (Baghdad-Karbala, Babylon-Karbala, Najaf-Karbala) Respectively. Where it is noticed that the concentration of gas increases in the district of Al-Hur, where it reached the highest value (0.034425) mol/m2, while the concentration decreases as we go out towards the district of Al-Hussainiya, the western stream, Al-Khayrat and the center of Karbala district, where it witnessed the lowest value (0.031459) mol/m2.

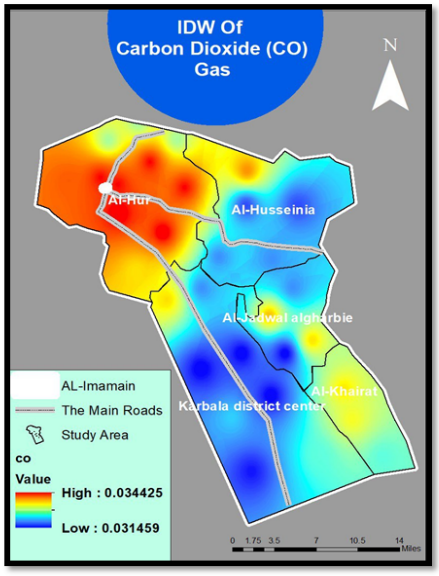

Figure (4) CO concentration of study area

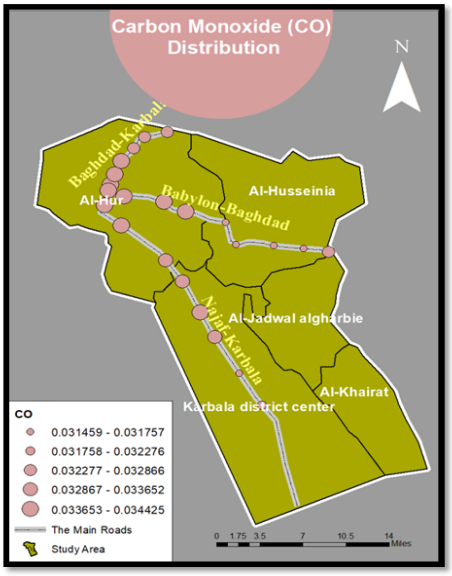

Figure (5) CO concentration of three roads

4.3. Ozone gas O3:

O3 is one type of gas that is formed due to photoreaction with existing air pollutants such as oxides of nitrogen (NOx) and volatile organic compounds (VOCs). The 8 hours mean concentration of O3 is 100 µg/m3. In ground level, the O3 is the pollutant in air that causes severe health effects on the human body[7] . Figure (6,7) shows that the eastern portion of the Al-Hussainiya district and the two sub-districts of Al-Khairat, Al-Jaddol Al-Gharbi, are the areas with the highest concentrations of ozone gas, with a maximum concentration of (0.1 29 141) mol/m2. While the ozone gas concentration falls in Al-Hur and the northern parts of the Al-Husseiniya district, where it achieved the lowest value (0.12538) mol/m2, the gas concentration rises elsewhere.

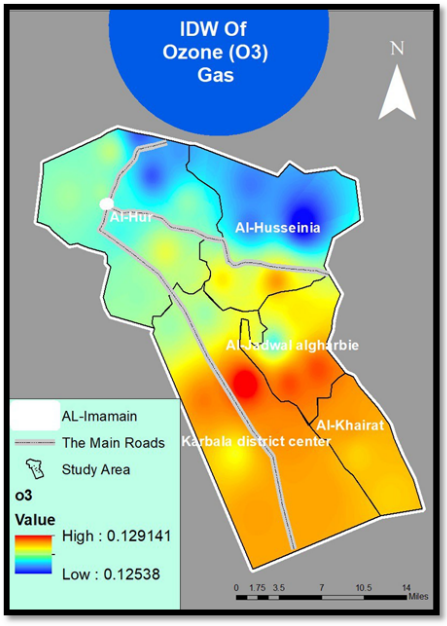

Figure (6) O3 concentration of study area

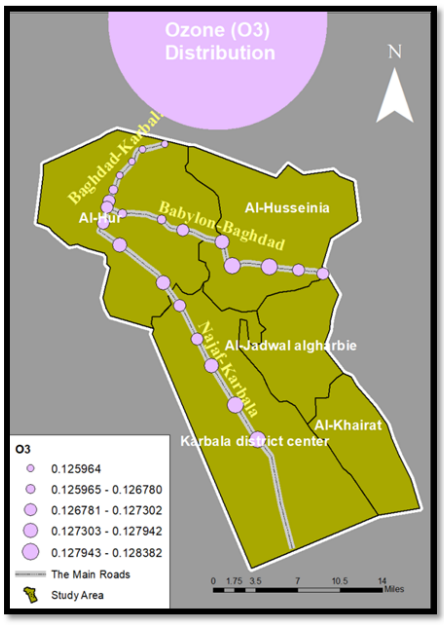

Figure (7) O3 concentration of three roads

4.4. Sulfur dioxide SO2:

SO2 is colorless, has bad odour and is a toxic natural pollutant in the air. The natural source of SO2 in air is due to action of volcanic activity. The other sources are fossil fuel, coal, oil, diesel, power plants, metals processing industries, smelting facilities and diesel

vehicles and SO2is also released from atmospheric secondary pollutants, such as sulphur aerosols, PM 2.5 and 10. [8]. Figures 8 and 9 show the distribution of sulfur dioxide gas across most of the study area, with the highest concentration occurring in Al-Husayniyyah, Al-Jaddol Al-Gharbi, and the southern part of the Al-Hur area (0.00147697) and the lowest concentration occurring in Al-Khairat and the Central offal-Hur side (0.00105495).

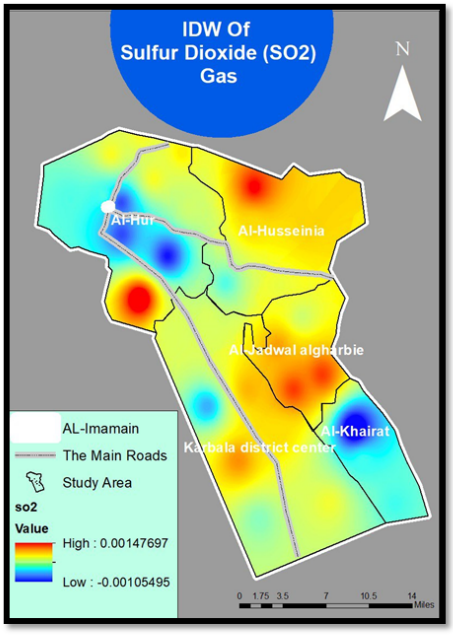

Figure (8) CO concentration of study area

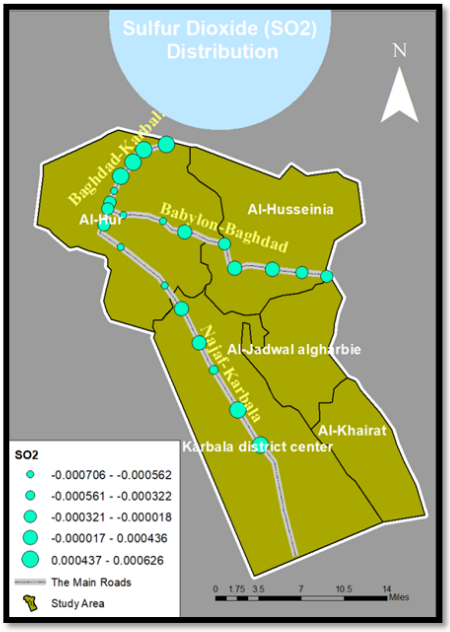

Figure (9) CO concentration of three roads

5. The mean and standard deviation value

In this study, satellite measurements of the HUI, SO2, CO, and O3 levels were made over the province of Karbala. As a result, the MA of the values derived inside the Karbala province's boundaries and displayed as Figures above. Based on the results (Figs. 4, 5, 6, 7,8 and 9), it is visually clear that the Karbala metropolis has the high mean concentrations of CO, SO2, and O3, but that the distribution of concentrations within the study area is irregular. This irregularity may be caused by the area's built-up areas, population density, and central business district. Table (2) shows the average concentrations of gases and the standard deviation in each of the study areas.

Table (2): Impact of LULC on the UHI, SO_2, CO, and O_3. (MOL/M2)

Name	Type	MEAN	MAX	MIN	STD
Al-Husseinia	CO	0.032465537	0.033848975	0.031757001	0.0004913
	SO2	0.000562281	0.001202987	-1.80E-05	0.000207113
	O3	0.126709963	0.128219992	0.125380024	0.00063067
	UHI	-0.65412233	2.149443865	-2.81633353	0.829764981
Al-Hur	CO	0.033834	0.034425	0.032321	0.000391
	SO2	0.000159	0.001477	-0.00071	0.000359
	O3	0.12692	0.127616	0.125964	0.000297
	UHI	-0.19978	2.225457	-2.62713	1.012424

Al-Jadwal algharbie	CO	0.032504524	0.033651955	0.031459015	0.000441194
	SO2	0.000681369	0.001089995	0.000313191	0.000187482
	O3	0.127977939	0.128618002	0.126822039	0.000406403
	UHI	-0.271248874	2.611011982	-2.747430563	0.784671817
Al-Khairat	CO	0.03297057	0.03346098	0.0323929	0.00023657
	SO2	-0.0001221	0.00063657	-0.001055	0.00027882
	O3	0.12811463	0.12839732	0.12797099	0.00010421
	UHI	0.79774262	2.86448812	-1.7479323	0.58271136
Karbala district center	CO	0.032187066	0.033513997	0.031459004	0.000429205
	SO2	0.000384749	0.000856984	-0.000287996	0.000198917
	O3	0.128046779	0.129140973	0.127101004	0.000365943
	UHI	0.433524402	2.502089977	-3.064390659	0.888765171

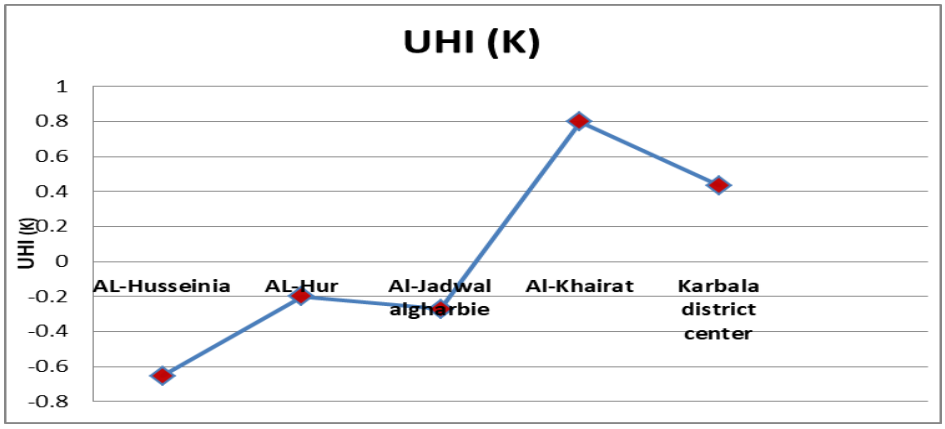

Figure (10)the mean of urban height inde

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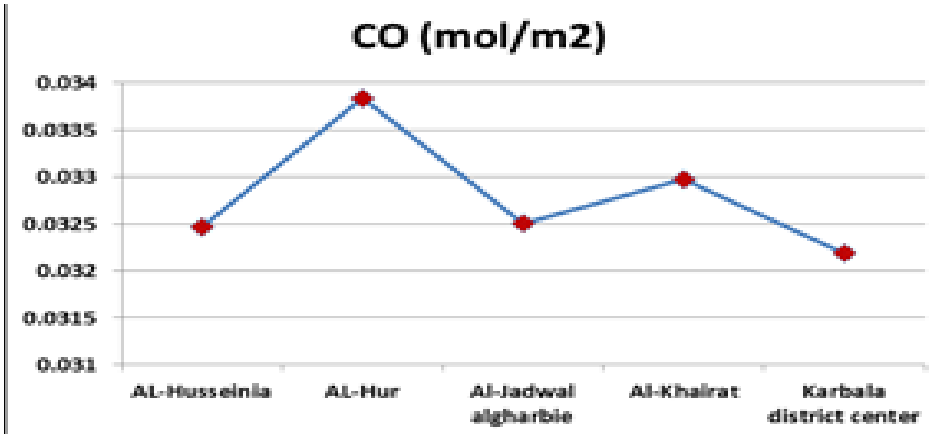

Figure (11)the mean of CO concentration

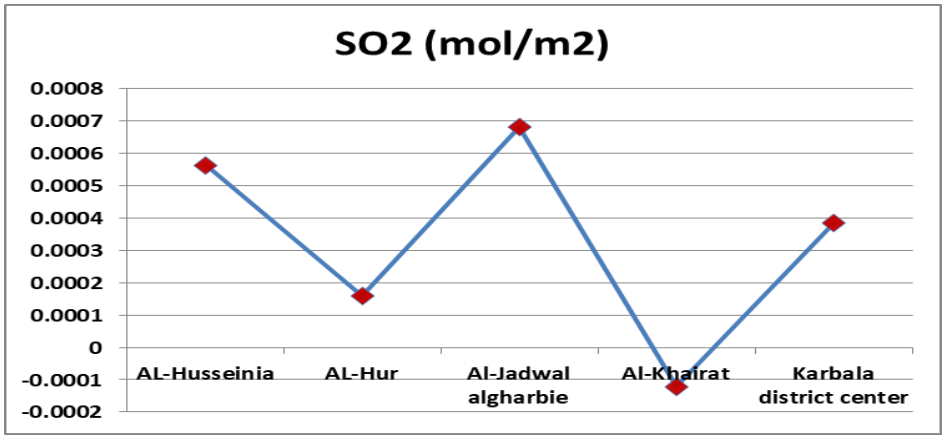

Figure (12)the mean of SO2 concentration

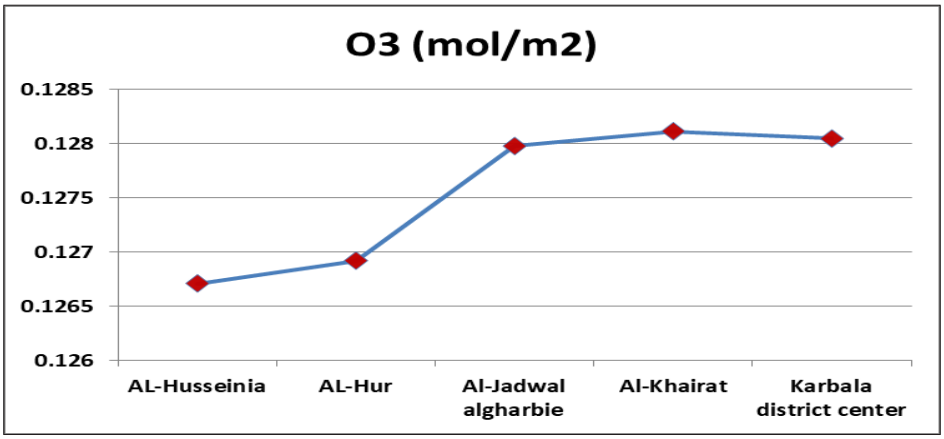

Figure (13)the mean of O3 concentration

Figure (10 -13) shows that the concentration of gases varies from region to another and at same region . Because the data was collected on September 17, 2022, the day of the Arbaeen visit, where the areas around the imam are densely populated and here the need for fuel and energy means for cooking and other purposes increases, the district of Al-Hur had the highest concentration of carbon monoxide gas, While the least concentration of it was in the center of Karbala district, on the road of visitors coming from Najaf, almost . As for sulfur dioxide gas, the Al-Jadwal algharbie district ranked first with the highest concentration of 0.000681369 mol /m2, while the Al-Khairat district recorded the lowest concentration among other regions, amounting to 0.0001221 mol/ m2. While the highest concentration of ozone gas was in the district of Al-Khairat and the lowest concentration of gas in the district of the Al-Husseinia.

6. Concentration of pollutants in some international countries.[9] ,[10]

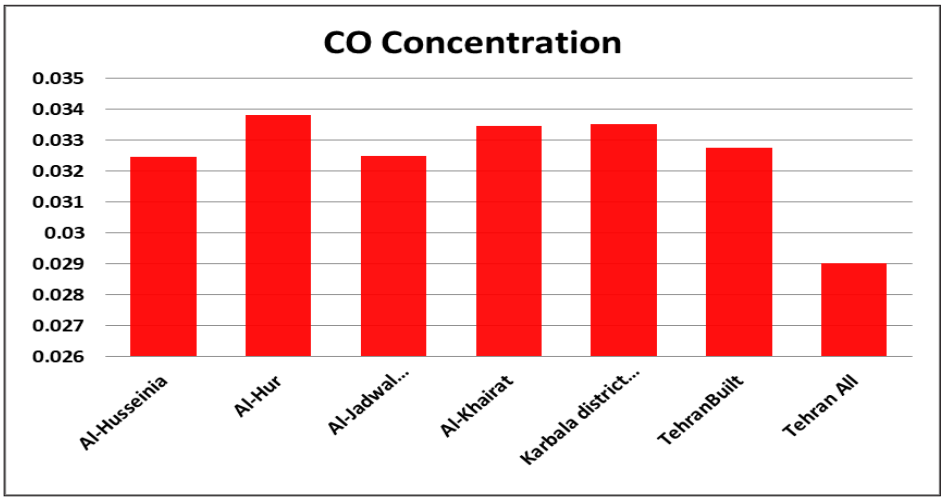

Figure (14) CO concentration on global cities

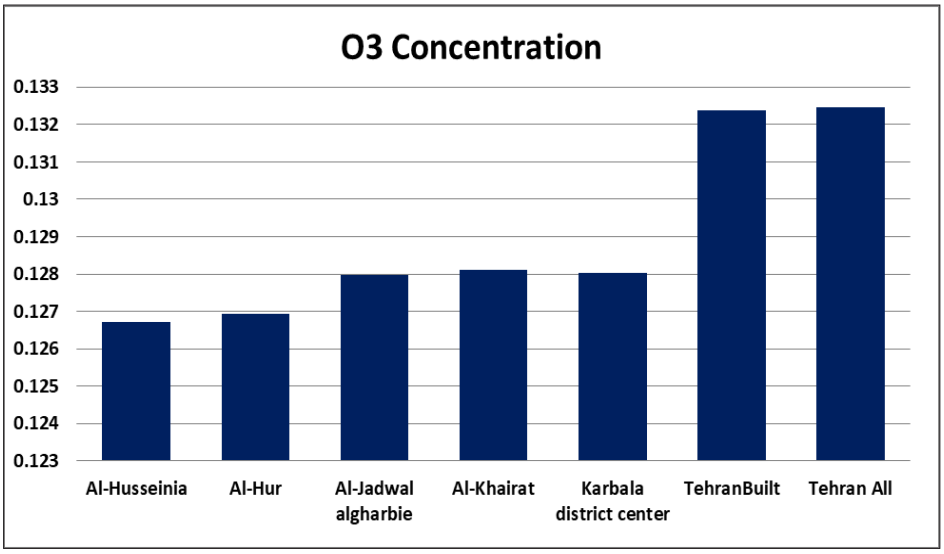

Figure (15) O3 concentration on global cities

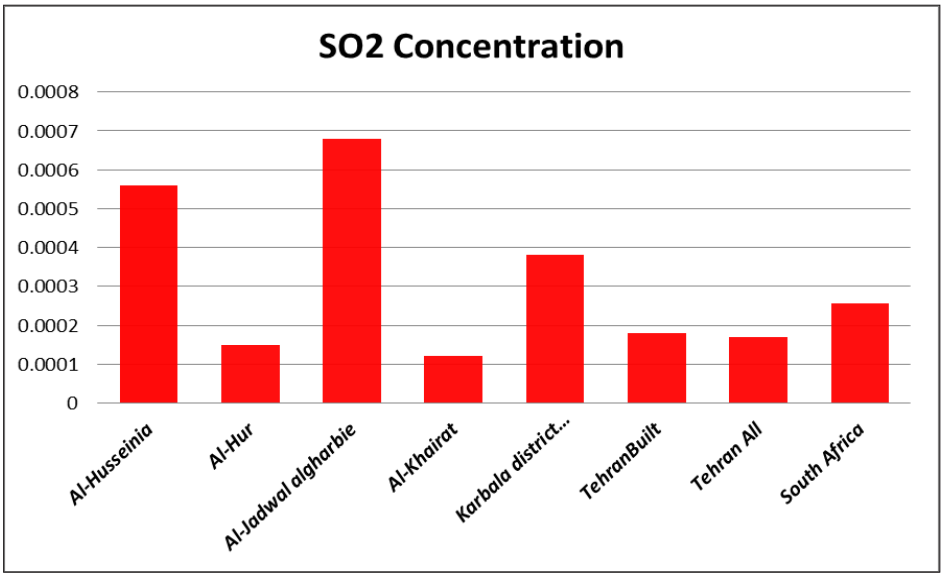

Figure (16) SO2 concentration on global cities

Figure 14 shows that the concentration of CO gas is high compared to the results of the city of Tehran, and the reason is that our data was collected on a day when the city of Karbala was densely populated, so the use of fuel, coal, car smoke, and the like increases from the sources. The results of works in the city of Tehran and South Africa were also taken into consideration in order to compare the results obtained with the global research that depended on the same satellite. As for ozone gas, see it to be present in great quantities above Tehran's sky due to the city's status as an industrial hub with numerous oil, mining, and other enterprises. Figure 16: The quantities of SO2 show convergence with South Africa and Tehran, with the exception of a pronounced increase in each of the western table and Al-Husseiniyah, which we will discuss in the conclusions.

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Conclusion:

Since millions of people visit Karbala on this day for Arbaeen, evidence of the concentration of several pollutants in the air was collected on 9/17/2022, making it necessary to investigate the amounts of such pollutants because they have an impact on human health. The impact of the LULC shift on the makeup of urban air pollution and LST has so far been established. However, the current study's use of remote sensing and GIS recognizes the vital link between the study area's vegetation and LST (which is naturally UHI). Additionally, the research methodology demonstrated that Kerala's city center and the urban region as a whole have the highest average concentrations of CO, SO2, and O3. And so on. Positive connections between CO, O3, and LST show the reciprocal impacts of LST, CO, and O3 values in the Karbala Governorate. The presence of large quantities of O3 gas in the southwestern side of the Karbala district center due to the presence of the Karbala refinery in that area, which in turn affects the area of Al-Hussainiya and the western stream due to the prevailing winds in the region. As for the SO2 foci, they are the result of the gas stations (the Al-Khairat station in the western stream and the Al-Hur station) and the presence of many brick factories in Al-Hussainiya. The overall conclusions of the study showed that local air quality and pollution levels can be monitored using Sentinel-5P TROPOMI data.

References :

1. Kaplan, G., & Yigit Avdan, Z. (2020). Space-Borne Air Pollution Observation from Sentinel-5P TROPOMI: Relationship Between Pollutants, Geographical and Demographic Data. International Journal of Engineering and Geosciences (IJEG), 5(3), 130137-.

2. Ialongo, I., Virta, H., Eskes, H., Hovila, J., & Douros, J. (2020). Comparison of TROPOMI/Sentinel-5 Precursor NO2 observations with ground-based measurements in Helsinki. Atmospheric Measurement Techniques, 13, 205218-.

3. Morozova, A. E., Sizova, O. S., Elagin, P. O., Agzamova, N. A., Fedash, A. V., & Lobzhanidze, N. E. (2022). Integral Assessment of Atmospheric Air Quality in the Largest Cities of Russia Based on TROPOMI (Sentinel-5P) Data for 2019–2020. Cosmic Research, 60(Suppl. 1), S57–S68.

4. Huda Jamal Jumaah, Mohammed Hashim Ameen, Shakeel Mahmood & Sarah Jamal Jumaah. (2023). Study of air contamination in Iraq using remotely sensed Data and GIS. Geocarto International, 38(1), 2178518.

5. Trenchev, P., Dimitrova, M., & Avetisyan, D. (2023). Huge CH4, NO2 and CO Emissions from Coal Mines in the Kuznetsk Basin (Russia) Detected by Sentinel-5P. Remote Sensing, 15(6), 1590.

6. Sharma, S., Zhang, M., Anshika, Gao, J., Zhang, H., & Kota, S. H. (2020). Effect of restricted emissions during COVID-19 on air quality in India. Science of The Total Environment, 728, 138878.

7. -Zhou, C., Su, F., Pei, T., Zhang, A., Du, Y., Luo, B., Cao, Z., Wang, J., Yuan, W., Zhu, Y., Song, C., Chen, J., Xu, J., Li, F., Ma, T., Jiang, L., Yan, F., Yi, J., Hu, Y., Liao, Y., & Xiao, H. (2020). COVID-19: Challenges to GIS with Big Data. Geography and Sustainability, 1(1), 77–87.

8. Zhu, S., Sun, J., Liu, Y., Lu, M., & Liu, X. (2020). The air quality index trend forecasting based on improved error correction model and data preprocessing for 17 port cities in China. Chemosphere, 252, 126474.

9. Fuladlu, K., & Altan, H. (2021). Examining land surface temperature and relations with the major air pollutants: A remote sensing research in case of Tehran. Urban Climate, 39, 100958.

10. Shikwambana, L., Mhangara, P., & Mbatha, N. (2020). Trend analysis and first time observations of sulphur dioxide and nitrogen dioxide in South Africa using TROPOMI/Sentinel-5 P data. International Journal of Applied Earth Observation and Geoinformation, 91, 102130.