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Environmental Assessment of Atmospheric Pollutant Concentrations in Al-Daura Refinery and its Adjacent Areas Using GIS and RS Techniques

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Abstract
Environmental contaminants have become a major worry for countries and communities worldwide. Greenhouse gases, such as CO_2 and CH_4, are among these pollutants that significantly contribute to the worsening of global warming. Deforestation, the conversion of agricultural land, and unsustainable human activities are some of the factors that have increased land use and exacerbated greenhouse gas emissions. The purpose of this study is to carefully track and evaluate the pollutants and greenhouse gases produced by human activity at the Al-Daura Refinery between 2013 and 2023, with an emphasis on April and August. The Giovanni platform provided the data for this investigation, using cutting-edge satellite technology to record gas concentrations and emissions worldwide and offering real-time insights authorized by the UN Climate Monitoring Organization. We found a concerning tendency after analyzing this data in ArcGIS and applying Inverse Distance Weighting (IDW) technology for predictive mapping:In contrast to 2013, the concentrations of SO_2, CO_2, and CH_4 soared in 2023, particularly in August. In April and August, the SO_2 gas concentrations rose from 457.01 to 458.59 and 452.04 to 459.93, respectively. For CO_2, the concentrations rose from 384.87 to 397.77 in April and from 390.62 to 416.07 in August. The concentrations of the gas rose, increasing from 6.488 to 8.34 in April and from 8.571 to 9.536 in August for CH_4 (2013-2023). This upward trend highlights the significant environmental impact of increased human activities at the Al-Doura refinery, emphasizing that it requires immediate attention and proactive measures to mitigate these harmful effects.

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Keywords:
Environmental Pollution, Daura Refinery, IDW Technique, RS, GIS Techniques.

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1. Introduction
There is no denying the seriousness of climate pollution and its pervasive impacts on living in the modern world. Human activity is mostly to blame for pollution, which puts our aspirational goals for advancement and the environment's inherent boundaries at serious odds [1]. Petroleum products are unquestionably convenient, but during their whole life cycle—from extraction to consumption they seriously harm the environment by poisoning our soil, water, and air. Our earth is suffering greatly as a result of the fundamental changes being made to its natural systems by this man-generated pollution [2]. The most pressing issue facing civilisation is climate change, which is brought on by the rising emissions of CO_2 and other dangerous pollutants. One of the most urgent problems facing the world today is environmental pollution, which is made worse by toxins' long air and ocean travel distances. Since breathing is an essential function for many living things, air pollution in particular is a serious threat to public health [3].
Furthermore, any damage done to one element of our surroundings sets off a domino effect that puts other interrelated elements in jeopardy [4]. Because clean air to breathe, clear water to drink, and sustainable food sources are vital to our well-being, human health and environmental health are so closely related. Realising this link is necessary in order to take prompt action to protect our environment for coming generations [5]. The

detrimental effects of pollution from the Al-Daura Refinery in Bagdad on neighbouring palm groves have been brought to light by an important study. Because of their high lead and sulphur content, the dates from these groves are considered unfit for human and animal consumption. By contaminating the soil, these pollutants harm plants, make their way up the food chain, and eventually build up in people through the ingestion of contaminated meats and fruits [6]. Additionally, air pollution upsets the equilibrium of our ecosystem and fuels worrying global problems like acid rain, climate change, and global warming. In order to take the required actions to solve this pressing issue, pollutant levels in the impacted areas can be precisely determined by using interpolation techniques to data from specific pollution hotspots [7]. An effective software tool for organising, analysing, storing, and visualising different kinds of geographic and geographical data is a Geographic Information System (GIS) [8]. This technology can successfully address a wide range of spatial difficulties when combined with the knowledge of a GIS analyst [9]. In order to gain a better understanding of environmental health, numerous researchers first used GIS technology to extensively examine the temporal and spatial distribution of pollutants [10]. Effective mitigation techniques, underlying causes, severe events, and the links to public health are the four main areas of focus for current research on air pollution and its mitigation. Through empirical studies, researchers have created a number of models that demonstrate effective air pollution reduction strategies. Motor vehicle emissions have been identified as one of the most major causes to air pollution in the United States, according to rigorous statistical approaches [11]. The concerning increase in industrial activity in China has been directly connected to rising air pollution levels. For example, research in Chengdu has used sophisticated numerical models and remote sensing data to identify the precise causes and sources of air pollution. Notably, the evidence underscores that many cancer cases in Shanghai can be traced back to air pollution, primarily from waste gas emissions [12]. Furthermore, the urban air quality in Kut City has been meticulously measured, and a detailed map of air contaminants has been crafted using innovative GIS methods [13]. Three key air pollutants SO_2, CO_2, and CH_4 were measured over 10 virtual stations that faithfully replicate real-world circumstances between 2013 and 2023 [14], with a focus on the Al-Doura Refinery and its environs. This study is essential because it emphasises how critical it is to make well-informed decisions and implement focused interventions in order to reduce air pollution and safeguard public health [15] [16]. This work's primary goal is to use GIS interpolation techniques to monitor and assess air pollution over the study area.

2. The Study Area Description

One of the biggest and most well-known oil refineries in Iraq, the Al-Doura Refinery is essential to the country's energy industry. It is situated in Baghdad's southeast; after the foundation stone ceremony in 1953, work on this integrated oil industrial complex started in 1955. With an impressive daily output capacity of 140,000 barrels, the refinery spans an area of 2,500,000 square meters and efficiently channels oil from the productive fields in the Kirkuk and Khanaqin governorates [17]. In addition to being a major producer of oil, this cutting-edge facility also produces a variety of other vital goods, such as diesel, kerosene, jet fuel, liquid petroleum, automobile petrol, crude oil, grease, wax, asphalt and much more. Additionally, it boasts a modern factory capable of manufacturing around 80,000 plastic containers each month to be filled with these valuable products. However, it is important to address the growing concerns regarding the refinery's impact on local communities. In the late 1950s, when the refinery was first established, Al-Doura area was sparsely populated. Today, the Iraqi Parliamentary Health and Environment Committee has rightly called for relocating Al-Doura refinery to ensure compliance with environmental standards and protect residents from potential harm caused by industrial activity within populated areas. Baghdad's desert climate contributes to extreme summer temperatures that can soar above fifty degrees Celsius, accompanied by arid conditions. The city faces significant environmental challenges, including rising carbon levels, desertification, and violent dust storms linked to global warming and Iraq's arid environment.

According to estimates from 2013, Baghdad's population stood at approximately 7,596,860, and projections by the Iraqi Ministry of Planning suggest it could reach 9 million by 2022. With the city covering an area of 4,555 square kilometers, it is clear that proactive measures are needed to safeguard the health and well-being of its growing population. The future of Baghdad and its residents depends on balancing industrial progress with environmental responsibility. as shown in Fig. 1.

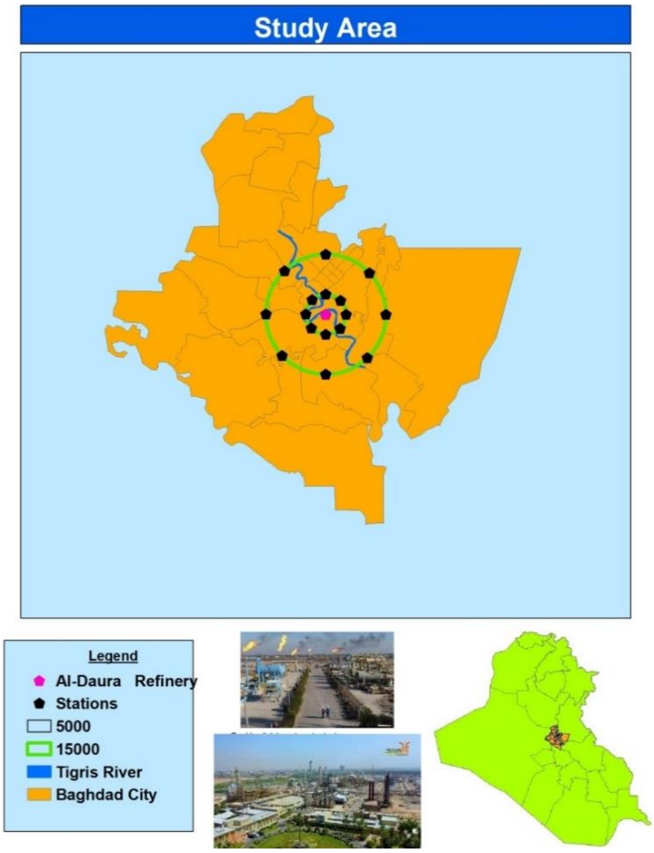

Figure 1: Study Area and location of stations, the first circle is five kilometres away from Masy al-Dawra, and the second large circle is ten kilometres away from the centre.

3. Material and Methodology

The research methodology is based on the spatial distribution of each greenhouse gas (SO_2, CO_2, CH_4) concentration in the study area. It was defined in three circles centered on Al-Dora refinery station. The first circle was five kilometers away from the station, the second circle was ten kilometers away, and the third circle was fifteen kilometers away. Assuming a 360-degree wind direction throughout the year, site stations supposed to intersect with the x-y axis point, consisted of sixteen stations. It is believed that the concentrations of these gases vary in these hypothetical stations according to their proximity and distance from the refinery station. The coordinates of these stations were taken using a Global Positioning System device (GPS); their decimal coordinates were measured in a precise degree (φ, λ). These coordinates were converted to the metric scale (x, y) to match the simulation of Landsat 8 satellite images and to obtain extreme accuracy in measurements. The platform Giovanni for earth observation and meteorological services of NASA were relied upon, and its services are distributed free of charge to researchers around the world according to the decisions of the climate change conferences in 2015 in Paris. Predictive maps were produced using the interpolation technique, which is a tool in the GIS program version 8, from which the distribution of greenhouse gas concentrations and their impact on the study area are known, as shown in Fig. 2.

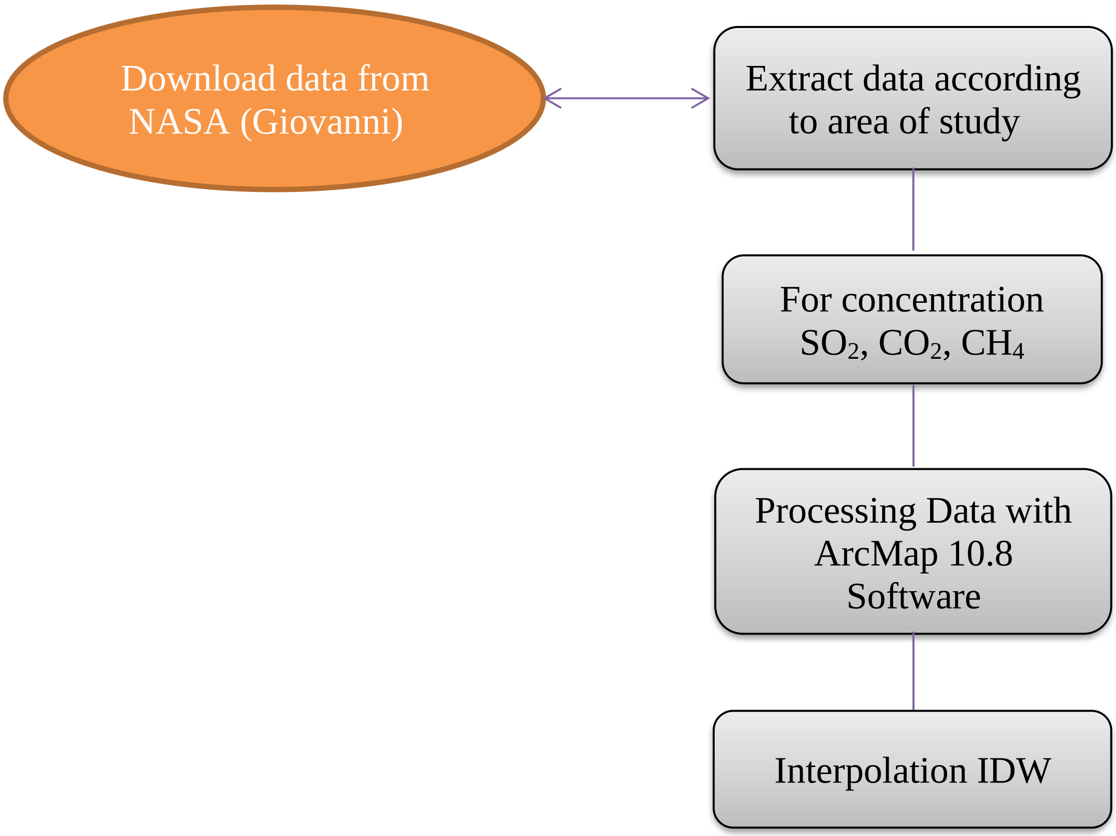

Figure 2: Work diagram, Methodology of study area.

3. 1. Data Acquisition

The study area represents the Al-Daura Refinery and its adjacent areas in the city of Baghdad. Data were obtained from NASA (Giovanni) for pollutants (SO_2, CO_2, CH_4) for 2013 and 2023 in April and August, as shown in Tables 1, 2, 3, and 4.

Table 1: Pollutants concentration for April 2013.

NO	Latitude (φ)	Longitude (λ)	Y- Coordinate (UTM)	X- Coordinate (UTM)	SO_2 (ppm)	CO_2 (ppm)*	CH_4 (ppb)**
1	33.28453	44.48367	3682862.616	451999.514	397.9879	388.5366	5.254365
2	33.25356	44.46887	3679343.212	450641.148	381.4157	381.9644	3.682083
3	33.23843	44.43149	3677923.102	446998.256	342.9921	383.5408	5.258507
4	33.25034	44.39308	3679219.724	443540.596	412.9672	391.5159	5.233576
5	33.28248	44.3758	3682800.872	441935.254	341.7663	382.315	1.932737
6	33.31481	44.39349	3686443.754	443478.852	312.9222	383.4709	2.18861
7	33.32861	44.43092	3687802.13	446936.512	390.8912	381.4399	3.15762
8	33.31582	44.46853	3697866.39	446936.512	342.9222	383.4709	2.18861
9	33.41878	44.43033	3693235.595	457803.443	343.4218	383.9705	2.68817
10	33.37701	44.54918	3682739.128	462002.03	344.4923	385.041	3.758698
11	33.28484	44.59059	3672427.893	457741.699	340.9913	381.54	2.257728
12	33.19086	44.54763	3667920.586	447060	340.4668	381.0155	1.933265
13	33.14886	44.43208	3672242.661	436316.557	340.9913	381.54	2.257728
14	33.18625	44.31859	3682615.64	431994.482	343.5677	384.1164	2.834152
15	33.2805	44.26927	3693173.851	436007.837	342.0436	382.5923	1.810055
16	33.37529	44.31118	3682769.64	447055.67	340.5432	381.0919	2.809615
17	33.28418	44.43036	3667920.586	462002.03	457.2281	397.7768	6.494523

* ppm =parts per million

** ppb = parts per billion

Table 2: Pollutants concentration for August 2013.

NO	Latitude (φ)	Longitude (λ)	Y-Coordinate (UTM)	X- Coordinate (UTM)	SO_2 (ppm)	CO_2 (ppm)	CH_4 (ppb)
1	33.28453	44.48367	3682862.616	451999.514	385.7696	368.5605	5.43652
2	33.25356	44.46887	3679343.212	450641.148	396.2941	369.085	5.960983
3	33.23843	44.43149	3677923.102	446998.256	337.8705	370.6614	9.537407
4	33.25034	44.39308	3679219.724	443540.596	336.6447	369.4356	3.311637
5	33.28248	44.3758	3682800.872	441935.254	452.1065	384.8974	8.773423
6	33.31481	44.39349	3686443.754	443478.852	307.8006	370.5915	4.46751
7	33.32861	44.43092	3687802.13	446936.512	407.8456	378.6365	7.512476
8	33.31582	44.46853	3697866.39	446936.512	337.8006	370.5915	4.46751
9	33.41878	44.43033	3693235.595	457803.443	338.3002	371.0911	4.96707
10	33.37701	44.54918	3682739.128	462002.03	339.3707	372.1616	6.037598
11	33.28484	44.59059	3672427.893	457741.699	335.8697	368.6606	4.536628
12	33.19086	44.54763	3667920.586	447060	335.3453	368.1361	4.012165
13	33.14886	44.43208	3672242.661	436316.557	339.8697	368.6606	4.536628
14	33.18625	44.31859	3682615.64	431994.482	388.4461	371.237	5.113052
15	33.2805	44.26927	3693173.851	436007.837	336.922	369.7129	3.588955
16	33.37529	44.31118	3682769.64	447055.67	385.4216	368.2125	5.088515
17	33.28418	44.43036	3667920.586	462002.03	392.8664	375.6572	7.533265

Table 3: Pollutants concentration for April 2023.

NO	Latitude (φ)	Longitude (λ)	Y-Coordinate (UTM)	X- Coordinate (UTM)	SO_2 (ppm)	CO_2 (ppm)	CH_4 (ppb)
1	33.28453	44.48367	3682862.616	451999.514	424.5152	390.6245	7.087576
2	33.25356	44.46887	3679343.212	450641.148	392.9637	381.073	5.536083
3	33.23843	44.43149	3677923.102	446998.256	354.5401	382.6494	7.112507
4	33.25034	44.39308	3679219.724	443540.596	419.5359	387.6452	1.023034
5	33.28248	44.3758	3682800.872	441935.254	353.3143	381.4236	3.786737
6	33.31481	44.39349	3686443.754	443478.852	324.4702	382.5795	4.04261
7	33.32861	44.43092	3687802.13	446936.512	402.4392	380.5485	5.01162
8	33.31582	44.46853	3697866.39	446936.512	354.4702	382.5795	4.04261
9	33.41878	44.43033	3693235.595	457803.443	354.9698	383.0791	8.3231
10	33.37701	44.54918	3682739.128	462002.03	356.0403	384.1496	2.258698
11	33.28484	44.59059	3672427.893	457741.699	352.5393	380.6486	0.757728
12	33.19086	44.54763	3667920.586	447060	362.0148	380.1241	0.433265
13	33.14886	44.43208	3672242.661	436316.557	352.5393	380.6486	0.757728
14	33.18625	44.31859	3682615.64	431994.482	355.1157	383.225	1.334152
15	33.2805	44.26927	3693173.851	436007.837	353.5916	381.7009	0.310055
16	33.37529	44.31118	3682769.64	447055.67	352.0912	380.2005	1.309615
17	33.28418	44.43036	3667920.586	462002.03	458.7761	384.1932	8.348523

Table 4: Pollutants concentration for August 2023.

NO	Latitude (φ)	Longitude (λ)	Y-Coordinate (UTM)	X- Coordinate (UTM)	SO_2 (ppm)	CO_2 (ppm)	CH_4 (ppb)
1	33.28453	44.48367	3682862.616	451999.514	415.8652	409.8369	8.211076
2	33.25356	44.46887	3679343.212	450641.148	384.3137	400.2854	2.659583
3	33.23843	44.43149	3677923.102	446998.256	345.8901	401.8618	8.236007
4	33.25034	44.39308	3679219.724	443540.596	419.8859	406.8576	4.146534
5	33.28248	44.3758	3682800.872	441935.254	344.6643	400.636	4.910237
6	33.31481	44.39349	3686443.754	443478.852	355.8202	401.7919	3.16611
7	33.32861	44.43092	3687802.13	446936.512	393.7892	399.7609	6.13512
8	33.31582	44.46853	3697866.39	446936.512	345.8202	401.7919	5.16611
9	33.41878	44.43033	3693235.595	457803.443	346.3198	402.2915	9.4466
10	33.37701	44.54918	3682739.128	462002.03	347.3903	403.362	3.382198
11	33.28484	44.59059	3672427.893	457741.699	343.8893	399.861	1.881228
12	33.19086	44.54763	3667920.586	447060	353.3648	399.3365	1.556765
13	33.14886	44.43208	3672242.661	436316.557	343.8893	399.861	8.881228
14	33.18625	44.31859	3682615.64	431994.482	346.4657	402.4374	2.457652
15	33.2805	44.26927	3693173.851	436007.837	344.9416	400.9133	1.433555
16	33.37529	44.31118	3682769.64	447055.67	343.4412	399.4129	2.433115
17	33.28418	44.43036	3667920.586	462002.03	460.1261	416.0978	9.472023

3. 2. Producing predictive maps

3. 2. 1. Interpolation Process

When calculating values at a location where sample data is deficient, interpolation assumes that items close to one another have increased similarity [18]. An accurate, reasonably dense, and uniformly distributed data point throughout the research region results in more trustworthy projected statistics. Otherwise, if there are few recorded points or the points are in groups with large data gaps, obtaining the estimate will be difficult regardless of the interpolation method used [19].

3. 2. 1. 1. Inverse Distance Weight (IDW)

The Inverse Distance Weight (IDW) method was used in this research. The proportional scaling method is a successful and simple interpolation method. A technique that supports the idea that specific points near a predictable point resemble investment values at that moment. The method is continuously used until each station affects the other locally. The distance replacement method uses a linear method to estimate attributed values at non-fictional locations. The inverse point function, which measures the distance between the eye points and the points of interest, applies to a collection of values in the sample. The assumption is that they are less comparable to the points sampled to the point they were not. IDW was appropriate in these situations. High spatial resolution, color sampling ratio, and large spatial size [20], as shown below in Eq. (1)

$$Z_j = \frac{\sum_{i=1}^{n} \frac{Z_i}{d_i^p}}{\sum_{i=1}^{n} \frac{1}{d_i^p}} \qquad (1)$$

where Z_i = value of known point, D_{ip} = distance to a known point, Z_j = the unknown point, and n = a user-selected exponent.

The most precise interpolation of air pollution conditions was offered by IDW. With a smaller error than the kriging technique, IDW was the most accurate interpolation method for estimating pollution levels in India [21]. The IDW offered the best accurate estimation of the air pollution conditions when compared to the Ordinary Kriging (OK) and Universal Kriging (UK) techniques

4. Result and Discussion

4. 1. Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is one of the most dangerous pollutants in the air [22], as most of the gases emitted from industrial sources of simple and complex industrial activities in areas where high concentrations occur. SO_2 constitutes more than 50% of the gases emitted from industrial sources, especially steam power plants and fossil fuel industries. Most of these stations depend on burning fossil fuels to produce energy or extract secondary components from evaporation and purification processes in fossil industries [23]. The products are most of the greenhouse gases, including sulfur dioxide, the danger of which lies in the pollution of public health and affecting the respiratory system of residents, especially those close to these factories [24]. The gaseous pollutants in the air (sulfur dioxide) were analyzed in the study area, as they were unstable. The results of the study showed that the concentrations of sulfur dioxide in 2023 were higher than in 2013 [25]. It was noticed that the highest concentrations of SO_2 gas were in the areas close to the main source, which is Al-Daura Refinery, in addition to the power generation stations in the Al-Dora area and the entrance to the Zaafaraniya area or Rashid Camp, as shown in Fig. 3(a, b, c, d).

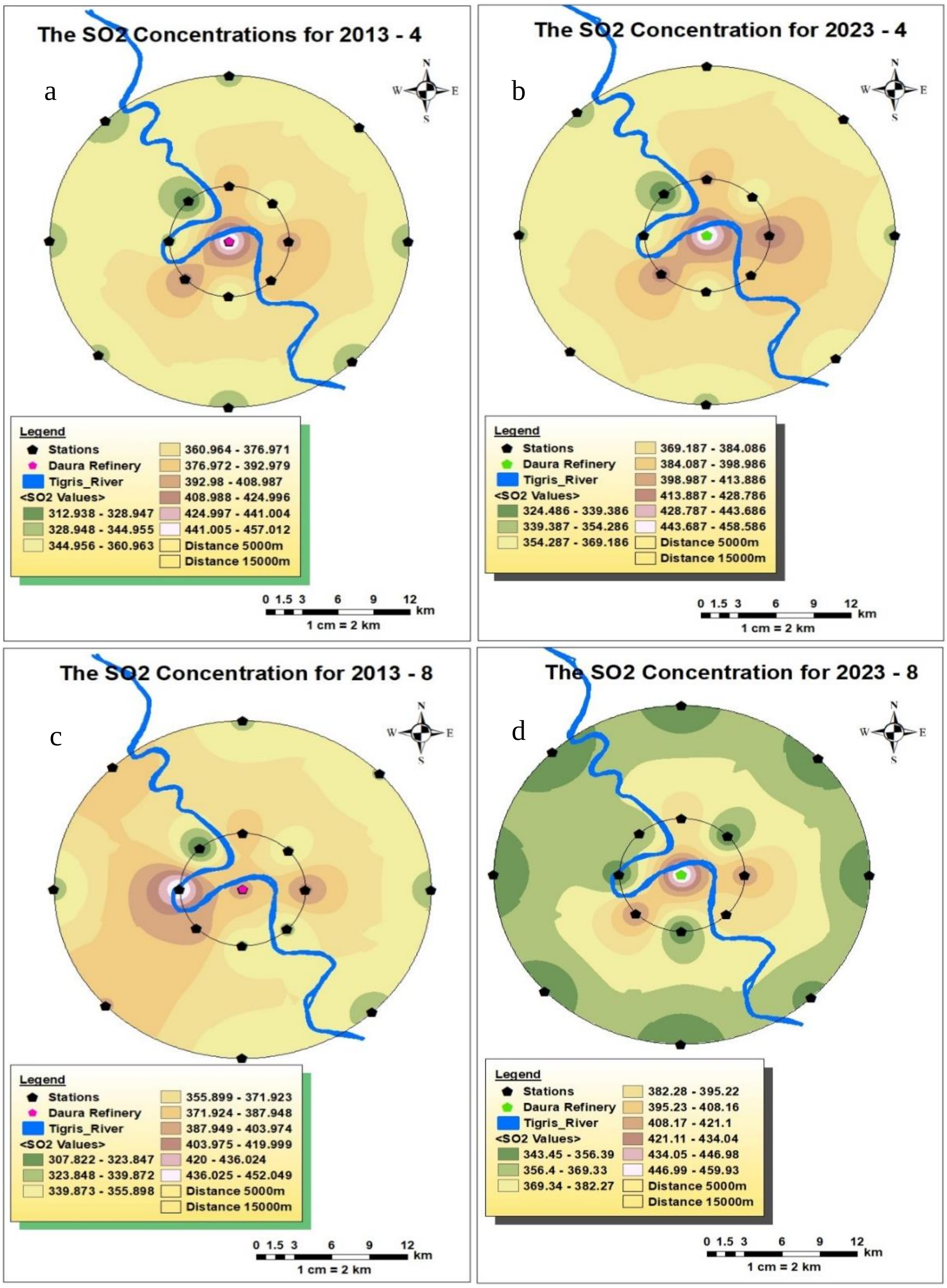

Figure 3: (a, b, c, d) SO_2 Concentration in the study Area for (2013 and 2023).

3.2. Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is a greenhouse gas that has been described as the major and worst climate pollutant. Carbon dioxide is one of the natural components of the atmosphere. Studying and analyzing CO_2 concentrations in the study area showed that there was an increase in its concentration when comparing the years 2013 and 2023, especially in August 2023, as shown in Figure 4 (a,b,c,d).

This is a very high concentration in the main source area, which is the Daura refinery, extending to the Zaafaraniya area to include the entrance to Rashid Camp, which has become a quarry for waste and the many fires that are widespread in this area, The safe level of CO_2 in the atmosphere is 350 ppm. The concentration of carbon dioxide in the Earth's atmosphere is currently about 412 ppm and rising.

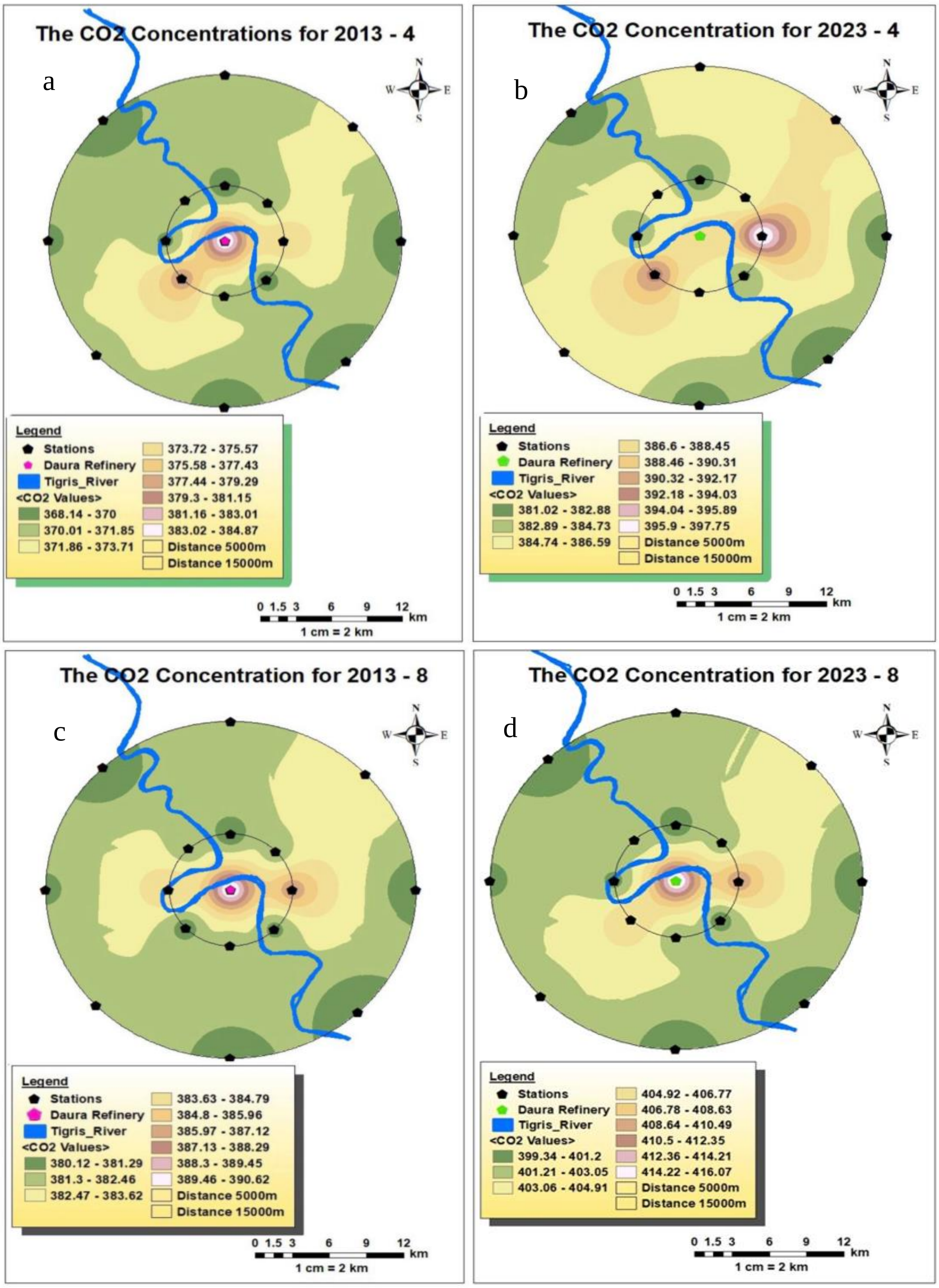

Figure 4: (a, b, c, d) CO_2 Concentration in the study area for (2013 and 2023).

3.3. Methane (CH_4)

Next to carbon dioxide, methane is an important greenhouse gas (GHG). Since pre-industrial times, methane levels in the atmosphere have risen from 722 parts per billion to 1,803 parts per billion, a 150% increase. This increase has resulted primarily from human activities such as biomass burning, oil and gas extraction, coal mining, landfills, livestock farming, wastewater treatment, and rice farming [26]. The results of this study showed that CH_4 concentrations increased in 2023 compared to 2013. The highest concentration of methane gas was 9.462 ppm ppm in August 2013 compared to the highest concentration in April, which was 6.488 ppm, while the methane concentration in 2023 and during the months of April and August was higher than in 2013, as shown in Figure 5 (a,b,c,d). The reason is attributed to random fires of organic materials and industrial waste in the Rusafa and Karkh sides of Baghdad city, including the area located at the entrance to the Zaafaraniya area, in addition to the burning of fossil fuels and gases for industrial activities in both the Al-Dora refinery and Al-Dora and Al-Quds power stations at the entrance of the Rashid camp, in addition to the Nahrawan brick factories that depend on burning fossil fuels.

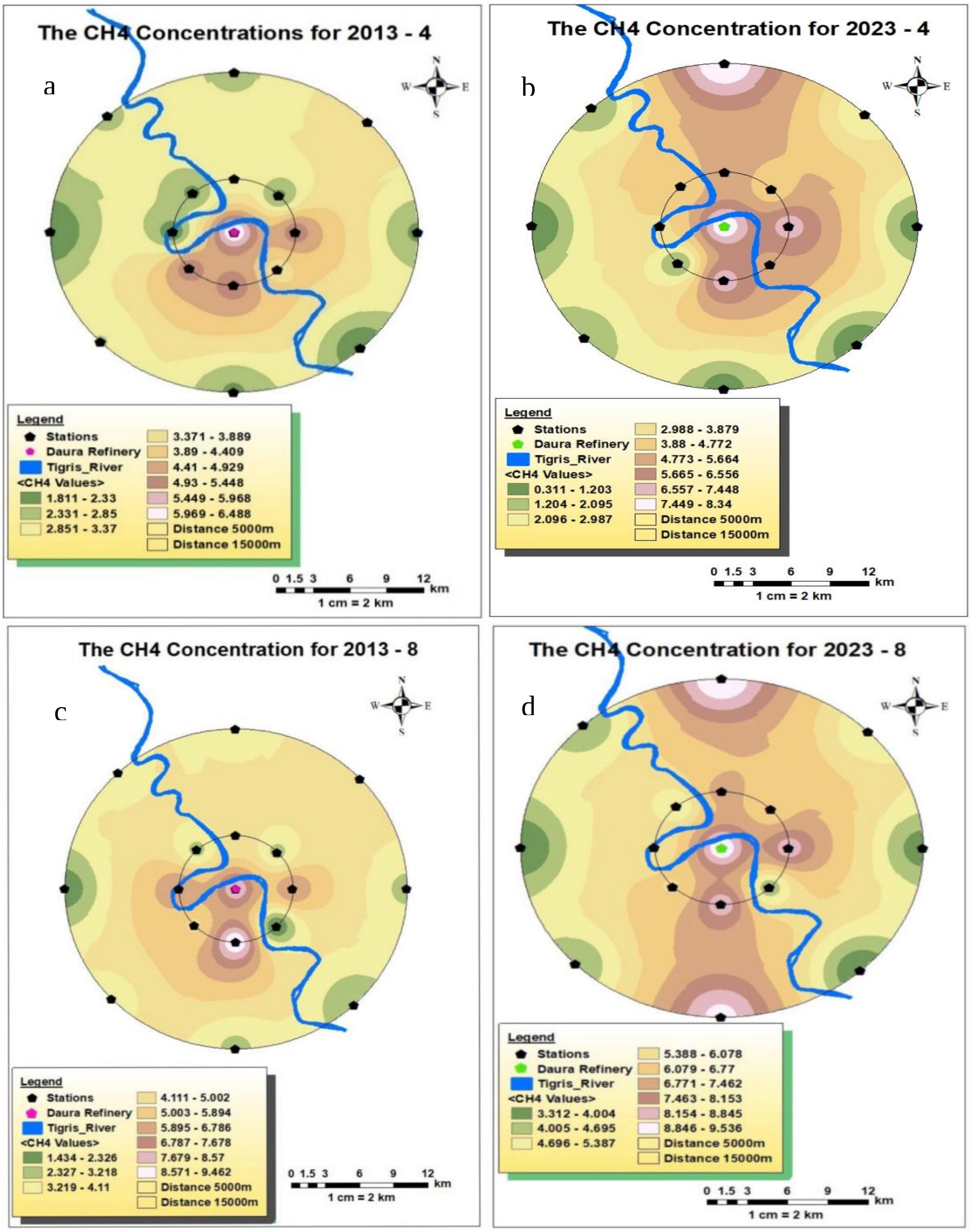

Figure 5: (a, b, c, d) CH_4 concentration in the study area for (2013 and 2023).

5. Conclusions

This study used remote sensing technology to demonstrate and monitor the changes that occurred in the quantities of polluted and greenhouse gases as a result of human activities and land uses, including the Al-Daura Refinery, which occupies an important location in the city of Baghdad and its surrounding areas as a result of urban expansion in the last two decades. This study analyzed the impact and quantities of pollutants and their spread in a radius of 15 kilometers. It showed the results by analyzing data obtained from NASA with its devices to monitor land cover activities for April and August of 2013 and 2023. The study concluded that the concentrations of pollutants (CO_2, SO_2, CH_4) increased in 2023 compared to 2013. This is for several reasons, in addition to the combustion of fossil fuels in the Al-Dora refinery, which was the most influential factor, and others, such as the increase in the number of vehicles on the streets and the presence of two power production stations. Electrical near the Al-Dora Refinery in the eastern and western parts of the refinery, in addition to the presence of several industrial laboratories in the northern part of the station, led to a remarkable rise in temperatures in the study area, and a decline in air quality of the atmosphere, which is a significant public health threat.

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التقييم البيئي لتراكيز الملوثات الجوية في مصفى الدورة والمناطق المجاورة لها باستخدام تقنيات نظم المعلومات الجغرافية والتحسس النائي

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الخلاصة

أصبحت الملوثات البيئية مصدر قلق كبير للدول والمجتمعات حول العالم. وتُعد غازات الاحتباس الحراري، مثل ثاني أكسيد الكربون والميثان، من بين هذه الملوثات التي تُسهم بشكل كبير في تفاقم ظاهرة الاحتباس الحراري. وتُعد إزالة الغابات، وتحويل الأراضي الزراعية، والأنشطة البشرية غير المستدامة من العوامل التي زادت من استخدام الأراضي وفاقمت انبعاثات غازات الاحتباس الحراري. تهدف هذه الدراسة إلى تتبع وتقييم الملوثات وغازات الاحتباس الحراري الناتجة عن النشاط البشري في مصفاة الدورة بدقة بين عامي 2013 و2023، مع التركيز على شهري أبريل وأغسطس. وقد وفرت منصة جيوفاني البيانات اللازمة لهذا البحث، باستخدام أحدث تقنيات الأقمار الصناعية لتسجيل تركيزات الغازات وانبعاثاتها في جميع أنحاء العالم، وتقديم رؤى آنية معتمدة من منظمة الأمم المتحدة لرصد المناخ. بعد تحليل هذه البيانات في ArcGIS وتطبيق تقنية ترجيح المسافة العكسية (IDW) لرسم الخرائط التنبؤية، لاحظنا اتجاهًا مثيرًا للقلق: فعلى عكس عام ٢٠١٣، ارتفعت تركيزات SO_2 وCO_2 وCH_4 بشكل حاد في عام ٢٠٢٣، وخاصةً في أغسطس. ففي أبريل وأغسطس، ارتفعت تركيزات غاز SO_2 من ٤٥٧.٠١ إلى ٤٥٨.٥٩، ومن ٤٥٢.٠٤ إلى ٤٥٩.٩٣ على التوالي. أما بالنسبة لثاني أكسيد الكربون، فقد ارتفعت تركيزاته من ٣٨٤.٨٧ إلى ٣٩٧.٧٧ في أبريل، ومن ٣٩٠.٦٢ إلى ٤١٦.٠٧ في أغسطس. وارتفعت تركيزات الغاز، من ٦٤٨٨ إلى ٨.٣٤ في أبريل، ومن ٨٥٧١ إلى ٩٥٣٦ في أغسطس بالنسبة لغاز CH_4 (٢٠١٣-٢٠٢٣). ويسلط هذا الاتجاه التصاعدي الضوء على التأثير البيئي الكبير الناجم عن زيادة الأنشطة البشرية في مصفاة الدورة، مؤكداً أن الأمر يتطلب اهتماماً فورياً وتدابير استباقية للتخفيف من هذه الآثار الضارة.

الكلمات المفتاحية: التلوث البيئي، مصفى الدورة، تقنية ترجيح المسافة العكسية، وتقنيات نظم المعلومات الجغرافية، الاستشعار عن بعد.