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Repercussion of Petroleum Industry and Vehicle Emissions on Kirkuk Air Quality Using GIS

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Abstract.

Crude oil and gas are crucial for energy supply throughout the globe. Drilling, transportation, and refining process of crude oil can release a lot of Volatile Organic Compounds, Formaldehyde, Carbon Monoxide, and Primarily Hydrogen Sulfides. Emissions from vehicle engines is another factor that causes a dramatic increase in carbon monoxide levels at traffic intersections. The Impact of these factors on Kirkuk air quality has been determined through measuring TVOCs, HCHO, CO, and H_2S at different sites in the city. It has been observed that the concentration of TVOCs exceeds the threshold limit in almost all the measured sites; in the northern part due to refineries presence or in the mid and southern part due to the high number of traffic crosses, where the highest observed value was 2.479 mg/m^3 at NOC refinery area. High levels of HCHO was also recorded at NOC refinery area. The environmental impacts of the petroleum industry were visible based on high detection of H_2S transcending the weighted average limit recommended by ACGIH at all areas near oil refineries and it has spread to Sekanyan urban area. Also, the LEL concentration measured denotes the existence of combustible gas near refineries and in two residential areas Araffa and Sekanyan. Besides, Traffic congestion demonstrated release of CO gas at traffic crosses exceeding the World Health Organization limitation and the Environmental Protection Agency limitation in Tisin and Noor Alkabir mosque traffic crosses respectively. Fortunately, the Oxygen level detected lies within the safe range.

Keywords: Oil industry, air pollution, IDW, developing countries, gas emissions.

1. Introduction

Air pollution is a complex problem nowadays due to industrial flourishment. However, it doesn't considered as a new phenomenon since many historical records pointed out this issue. The Roman annalist, Seneca expressed his indignation because

of the heavy air caused by the smoky chimneys(Lukacs & Rossano, 1967). Generally, the pollution rooted out from either natural sources or synthetic sources. Industries,

automobiles, and power plants form the major source of air pollution which are sub-classified under the man-made sources, such as oil industry operations that use an enormous amount of consumable fuel like those of crude oil refineries and power stations; caused by the high production of ashes, poisonous gases, and solid particle. Although marketing, transportation, and production of oil contribute to the pollution they have a minor air pollution problems in comparison with refineries("The Petroleum Refining Industry—Air Pollution Problems and Control Methods," 1964). The availability of substances and contaminants in the air that impact negatively on creatures' health or generate harmful environmental situation is termed as the Atmospheric pollution(Duha Karem , Hamzah Kadhim, 2017). Many countries consider air pollution in urban areas as an environmental problem; the source of this pollution produced mainly by combustion activities initiating mostly from industrial operations and automobiles; the combustion originates various air pollutants that are noxious to the humans and nature(Daly & Zannetti, 2007). World Health Organization report stated that in 2012, the number of death due to ambient air pollution were 3 million people and 85 million DALYs annually(Organization, 2016). The health effects of these pollutants can lead to more medication use, more doctors and emergency rooms will be required, and more death cases. Our air is composed mostly of Oxygen and Nitrogen with small quantities of argon, carbon dioxide, water vapour, and other gases. Moreover, it holds dust particles, pollen, bacteria, and spores. The air pollutant index (API) is used to aid people in making up their minds whether outdoor activities should be performed in a specific day or not(Jumaah, Ameen, Kalantar, Rizeei, & Jumaah, 2019).

The sources of pollution in Kirkuk are divided into two main sources: natural origins such as microorganisms and mineral materials and other industrial origins such as those resulting right from the ignition of fuel for industry, transportation and warming (Co, Co_2, No, H_2S). The air pollutants which will be included in this study are Hydrogen Sulfide (H_2S), Carbon Monoxide (CO), Formaldehyde (HCHO), and TVOC (total volatile organic compounds); the LEL (Lower Explosive Limit) for Calibration Gas will be measured as well. The air pollutants which will be included in this study are Hydrogen Sulfide (H2S), Carbon Monoxide (CO), Formaldehyde (HCHO), and TVOC (total volatile organic compounds); the LEL (Lower Explosive Limit) for Calibration Gas will be measured as well.

The objective of the this study is to measure the concentrations of air pollutants in Kirkuk city and determine the evidence of any impact of Crude Oil industries (crude oil refineries, gas stations, oil production fields) and vehicle emissions on the air quality with the usage of Geographic Information System (GIS) to map the air pollution.

1.1. HCHO and TVOC

Along with the Ozone and particular matter, Formaldehyde (HCHO) is considered as one of the most vital carcinogen in the environment and a concentration of 1 over one's lifetime will lead to nasopharyngeal and lung cancer according to the U.S. Environmental Protection Agency (EPA)(U.S. EPA, 2015).

Formaldehyde exists in open-air air because of photo oxidation of the normally presented methane and various organic compounds and as emissions from plants. Additional anthropogenic efforts to formaldehyde quantities in the environment include vehicle exhaust, ignition operations and manufacturing activities for instance resins production. The effect of Formaldehyde after short term exposure is illustrated in table 1. The normal environmental concentration of Formaldehyde is around 0.001mg/m^3 in outdoor air; while inside the city the average concentration is in the range of 0.003 to 0.005mg/m^3 (Knoeppel Helmut, Lars, & Bernd, 1990).

Total Volatile Organic Compounds (TVOCs) represent the emissions that comes from chemicals and toxins. TVOCs can cause serious damage to human body from minor irritation of eyes, throat, and nose to cancer according to the amount and period of exposure("Total volatile organic compounds - how do they affect your health?," 2019). The acceptable limit of TVOCs is ranged from 0 to 0.5mg/m^3, equal and higher levels than 0.5mg/m^3 is considered as unacceptable ("What are acceptable VOC levels in the air? - Tecam Group," n.d.).

Table 1. Impact of formaldehyde on humans after short term exposure (Knoeppel Helmut et al., 1990)

Effect	HCHO concentration (mg/m^3)
Odour detection	0.1
Iteration of eyes	0.5
throat Iteration	0.6

1.2. Carbon Monoxide

One of the most widespread and poisonous gases; it is generated due to the incomplete combustion of fuel containing carbon such as natural gas, gasoline, crude oil, and coal. High concentration of Carbon Monoxide in the air will leads to the lack of oxygen (O_2) transfer by hemoglobin and thus adversely affecting humans health which includes headaches, and chest pain for those with heart disease.

1.3. Hydrogen Sulfides

It is a toxic, flammable, and colourless pollutant gas . Hydrogen sulfides can be easily identified in low concentration (0.008-0.13 ppm) through its rotten eggs odor but this won't be possible at high concentration (100 ppm). Crippling of the olfactory receptor neuron has been documented at 150 ppm (Beauchamp et al., 1984). Nearly 90% of the Hydrogen sulfide in the environment arises from natural sources. H_2S comes up as a result of microbial reduction in compounds that contain sulfur; It is released from crude oil, impure or stagnant water, and coal. However, a little quantity

of H_2S is released from mud pots, volcanoes , and comparable geological formations(Chou, 2006). American Conference of Governmental Industrial Hygienists (ACGIH®) recommended a short term exposure limit (STEL) of 5 ppm and a time weighted average limit (TWA) of 1 ppm ("Safety and Health Topics | Hydrogen Sulfide - Standards | Occupational Safety and Health Administration," n.d.).

1.4. Combustible Gas(LEL)

Previous to an explosion or a fire occurrence, three circumstances have to be met at the same time, a fuel (i.e. combustible gas) and O_2 (air) must exist in certain proportions, along with an ignition source, such as a spark or a flare. The proportion of fuel plus the necessary oxygen that is needed differs with each combustible gas.

The Lower Explosive Limit (LEL) for that gas is defined as the lowest quantity of a specific combustible gas required to assist its ignition in atmosphere. Under this level, the combination is very "lean" to burn.

2. The methodology of the study

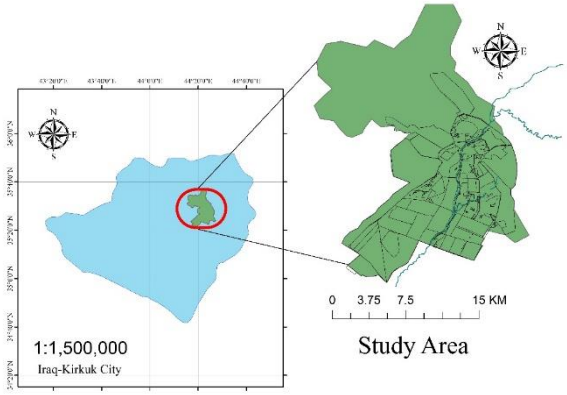
The importance of this research lays in figuring out the phenomenon of air pollution in Kirkuk city with explaining the factors that plays an important role in boosting it. Besides, guide the specialists and experts to pay attention to the seriousness of this matter to diminish its growth and provide a safe environment for the people and prevent the changes that affect them negatively.

3. Materials and Methods

3.1. Study Area

The area of the research is located at the north of Iraq, particularly in Kirkuk city which is boarded via geographic latitudes (35º 24' 38" N - 35º 24' 03" N) and geographic longitudes (44º 21' 32" E - 44º 22' 24" E) having an overall area around 9,679 km^2, it is situated to the north of Baghdad city by a distance equal to 286Km as shown in Fig.1. It has a connecting boarder from the northeast with Sulaymaniyah city and from the northwest with Mousel city and from the north with Erbil city and from the south with Tikrit city. Kirkuk is considered as the fifth biggest city in Iraq when it comes to the population and one of the vital oil cities with estimated reserves about 10 billion barrel of a good quality crude oil. As a result, the oil industry occupied a great importance in Kirkuk in terms of setting up several refineries and increase the field productions.

Figure 1. The area of study



Different locations of Kirkuk study have been selected for our study, some based on traffic congestions and other on oil industries. The exact coordinates are shown in Table 2 where readings have been recorded; the measurements were at least 5 meters away from buildings.

3.2. Instruments

The Smart Sensor 4 in 1 gas detector has been used to measure H_2S, CO, LEL%, and O_2 while TVOCs and HCOH have been measure using an Air Quality Tester.

Table 2. Study Locations

No.	Locations	Latitude	Longitude
1	Iskan (L1)	35.47206	44.41240
2	Rahimawa (L2)	35.49109	44.38761
3	Kat Refinery area (Gilly Awa) (L3)	35.60280	44.37227
4	Sekanyan (L4)	35.55977	44.36868
5	Near Castle of Kirkuk (L5)	35.46784	44.39340
6	Sona Guli (L6)	35.51227	44.41152
7	Darwaza (L7)	35.48045	44.42703
8	Noor Alkabir mosque traffic cross (L8)	35.42495	44.37283
9	Tisin Traffic cross (L9)	35.44829	44.37127
10	Araffa near NOC (L10)	35.48110	44.37493
11	Kirkuk Olympic Stadium area (L11)	35.44454	44.41658
12	Rashid Road (Domiz) (L12)	35.39833	44.37852
13	Kirkuk University cross section area (L13)	35.39759	44.34146

14	Shwan Refinery area (L14)	35.45072	44.56631
15	Panja Ali road (L15)	35.40048	44.44354
16	Ras Domez traffic cross (L16)	35.40424	44.35994
17	Motor vehicle dealers area (L17)	35.43038	44.35751
18	Kirkuk health directory traffic area (L18)	35.45101	44.38138
19	Xabat bridge traffic cross (L19)	35.47330	44.39074
20	Near North Oil Company Refinery (L20)	35.525082	44.337812

4. Results and Discussion

The concentrations of measured air pollutant are listed in table A1 in the appendix. The concentration of Carbon monoxide value ranged from 0.3 to 11.2 ppm as shown in Fig. 2, highest values of CO are distributed across traffic sections while the lowest has been observed in the eastern north part of the city. The maximum record is 11.2ppm at Tisin traffic cross which is higher than the maximum allowable concentration in living area; where the utmost permitted quantity in the living region is 9 ppm ("Carbon Monoxide: Keeping Safe," n.d.). Furthermore, CO has been recorded with high concentrations in other traffic crosses as well such as Near Castle of Kirkuk, Kirkuk University, Ras Domez, Motor vehicle dealers area, Xabat bridge, Kirkuk health directory with (5.2, 7.6, 6.3, 5.5, 7.6, 5.3) ppm respectively. Although, some readings were much lower than those measured in traffic crosses but it still considered as a high values in living areas such as Kat refinery area, Sekanyan, Shwan refinery area, Panja Ali road, and near North Oil Company Refinery with values (1.6, 1.02, 1.1, 1.2, 2) ppm respectively. The concentrations of CO documented at Kirkuk University traffic sections (7.6ppm) could exhibit the risk to the University students along with employees near that area. Fig. 3 demonstrates the comparison among the measured levels and the limitations of other standards (EPA, and WHO); where EPA and WHO limitations are 9 ppm and 11 ppm respectively (Kolb, 2018)("Carbon monoxide - WHO Guidelines for Indoor Air Quality: Selected Pollutants - NCBI Bookshelf," n.d.). Tisin traffic cross has shown a dangerous CO level higher than EPA and WHO limitations. Furthermore, the record at Noor alkabir mosque traffic cross has passed the EPA limitation as well but it was less pollutant than Tisin traffic cross.

Figure 2. Carbon monoxide concentration (ppm) along Kirkuk city

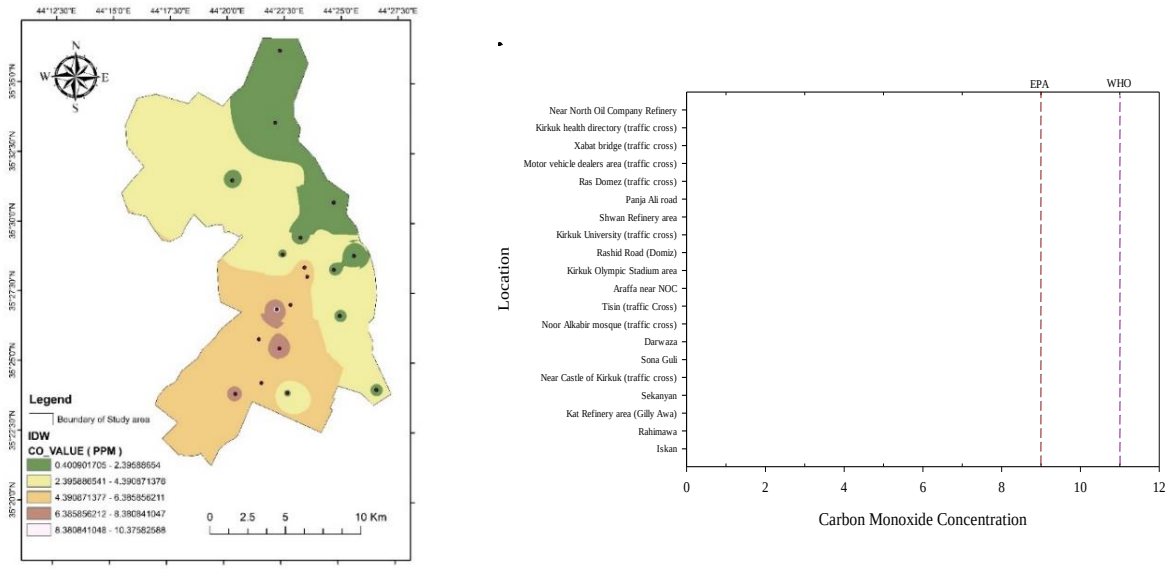
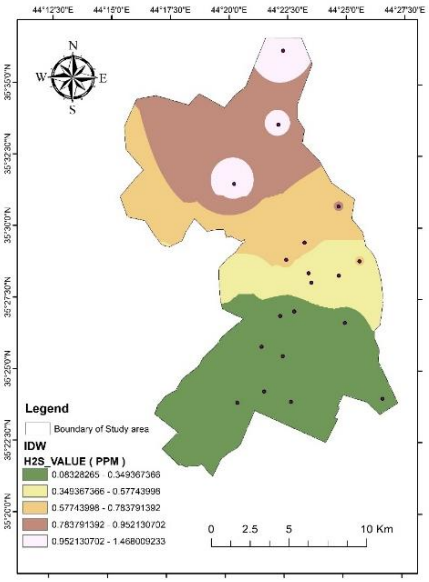


Figure 3. Carbon monoxide concentration with respect to EPA and WHO limitations

The level of H_2S has been recorded in a variety of places with the highest measurements at the north part of the city as a result of North Oil Company and Kat refinery emissions as shown in Fig.4, where the influence of the company has mainly spread to the region around it and in general to the northern part of the city. The highest H_2S readings recorded were 1.5, 1.3, 1.2, and 1.1 ppm at North oil company refinery area, Kat refinery area, Shwan refinery area, and Sekanyan respectively as seen in Fig. 5; all of these values are higher than the weighted average limit recommended by ACGIH. Whilst the lowest recorded readings were in the southern part of the city away from the pollutants of oil industries; where Kirkuk University area shows the lowest measured H_2S which was around 0.08ppm. As for the Shwan refinery, it didn't seriously affect the environment of the city due to its far location from the city in comparison to previously mentioned refineries as illustrated in Fig.6.

Figure 4. Hydrogen Sulfide concentration (ppm) across Kirkuk city



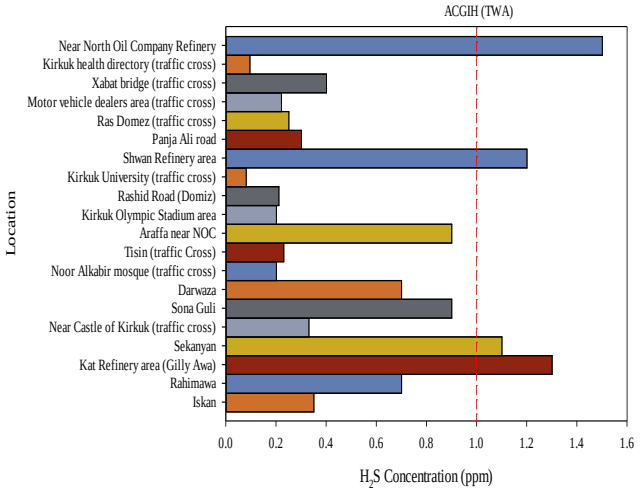
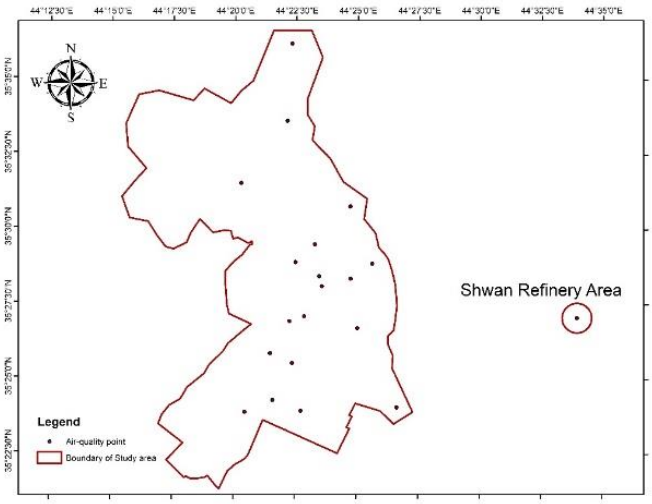


Figure 5. Hydrogen sulfide concentration along Kirkuk city

Figure 6. Location of Shwan Refinery from Kirkuk City



The value of TVOC fluctuated from 0.008 to 2.479 mg/m^3 along Kirkuk city as shown in Fig. 7. Considering the measured values, there are significant differences between the measured values at oil industries areas plus the traffic crosses areas and other sites; where the maximum values observed was 2.479 mg/m^3 at North oil Company refinery area. On the other hand, the lowest value recorded was 0.008 mg/m^3 at Rashid road (Domiz). As illustrated in Fig. 8, the outdoor air in Kirkuk is very polluted with TVOCs, many sites recorded higher value than 0.5 mg/m^3 which in return considered as unsafe for humans. The only outdoor sites with low TVOCs

values were Panja Ali road, Rashid road, Kirkuk Olympic Stadium area, Rahimawa, and Iskan; where the lowest value recorded was 0.008mg/m^3 at Rashid Road (Domiz).

Fig.9 shows the outdoor variation of HCHO along Kirkuk City, several sites showed lower concentration levels than the eye irritation level that is around 0.3 mg/m^3. The only site that recorded a high value which is fairly close to 0.3mg/m^3 is at the area near NOC refinery. Overall the values were reasonably acceptable except those area near oil industries. However, the measurement levels raised at traffic cross areas as shown in Fig.10 and the lowest value recorded were at Kirkuk Olympic stadium area 0.035 mg/m^3.

Figure 7. Volatile Organic Compounds Concentration along Kirkuk city

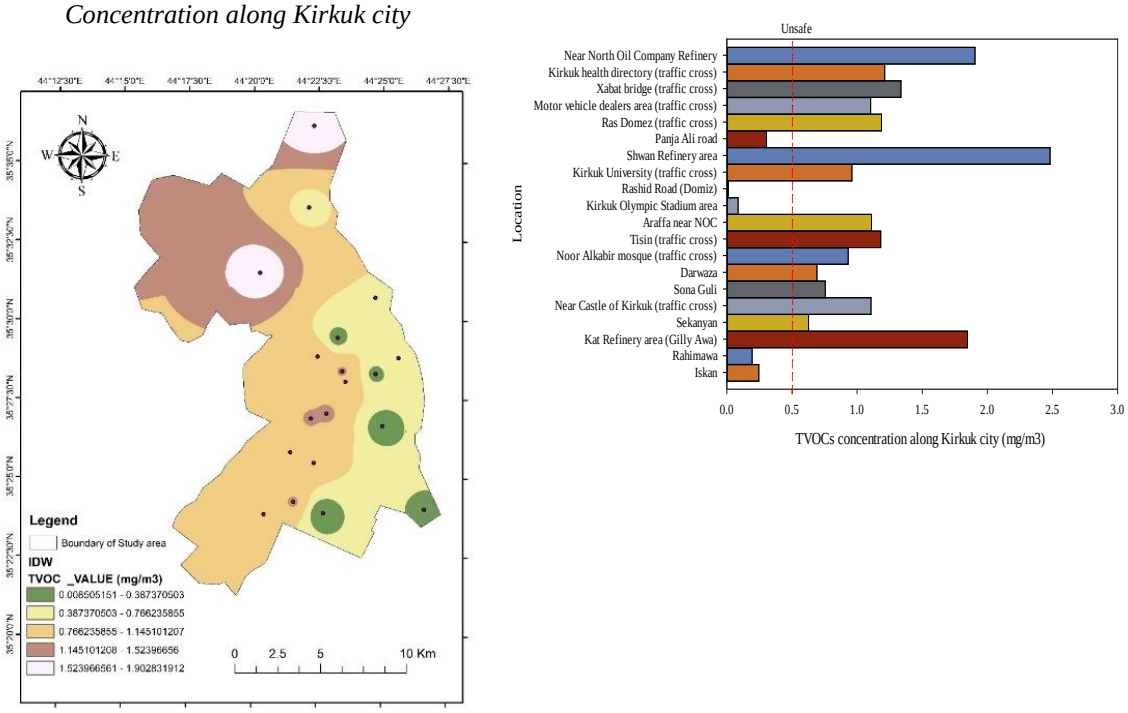
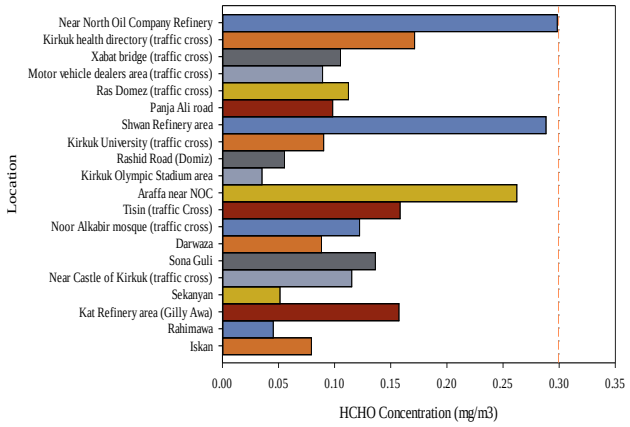


Figure 8. Volatile Organic Compounds Concentration with respect to the allowable limit

Figure 9. Formaldehyde concentration along Kirkuk city



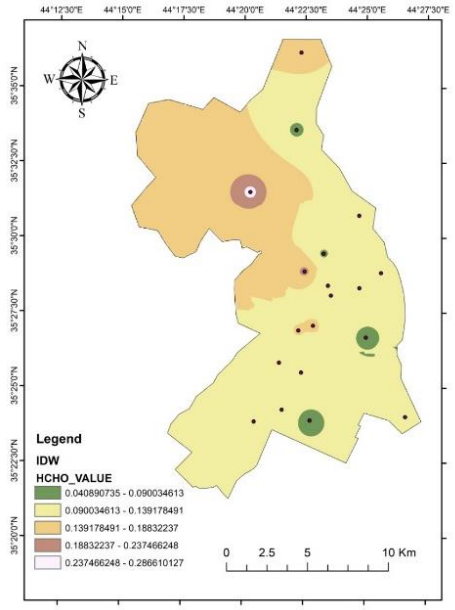
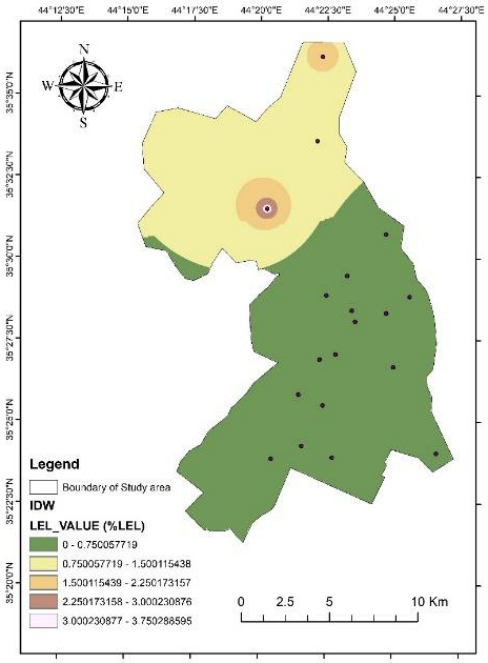


Figure 10. HCHO concentration at various sites in Kirkuk city

The LEL indicates the combustible gases that emitted from industries. In this study, LEL has been detected in several sites in the northern part of Iraq ranging from 0.9 to 3.9 %LEL as illustrated in Fig.12. The peak level has been measured at North oil company refinery area (3.9%LEL) which is an indication of the high presence of a combustible gas in the air. Detecting LEL near refineries was already expected but what causes a shock was detecting LEL at Urban areas in both Araffa and Sekanyan with 0.9 and 1.3 ppm respectively.

Finally, the Oxygen concentration were fluctuating between 20.1 to 20.7 %Vol, with an average value of 20.336 %vol as shown in Figures 13 and 14. O_2 concentrations along Kirkuk are within the safest range determined by The Occupational Safety and Health Administration (OSHA); the latter identified the ideal range of O_2 in the atmosphere for human beings between 19.5 and 22 %vol ("Shipyard Employment eTool > Confined or Enclosed Spaces and Other Dangerous Atmospheres: Oxygen-Deficient or Oxygen-Enriched Atmospheres," n.d.).

Figure 11. LEL Concentration along Kirkuk city (%LEL)



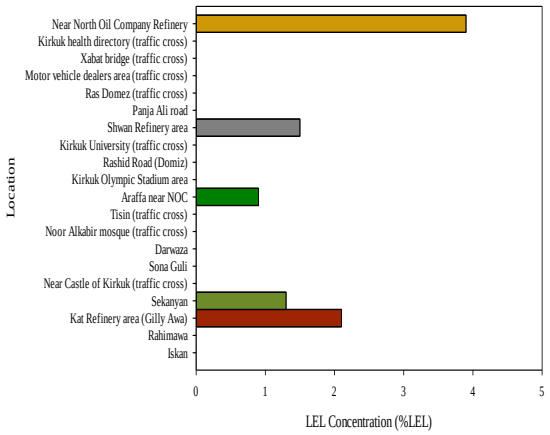


Figure 12. LEL Concentration level in various sites

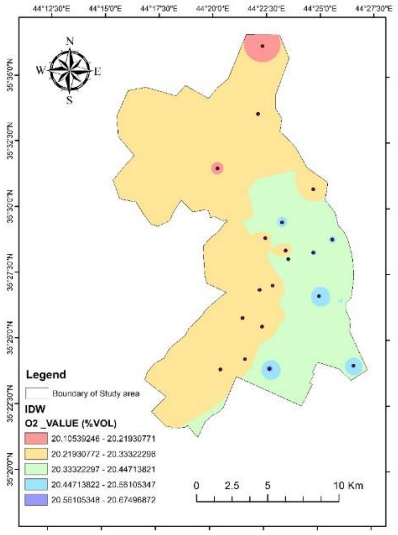


Figure 13. O2 concentration along Kirkuk city (%Vol)

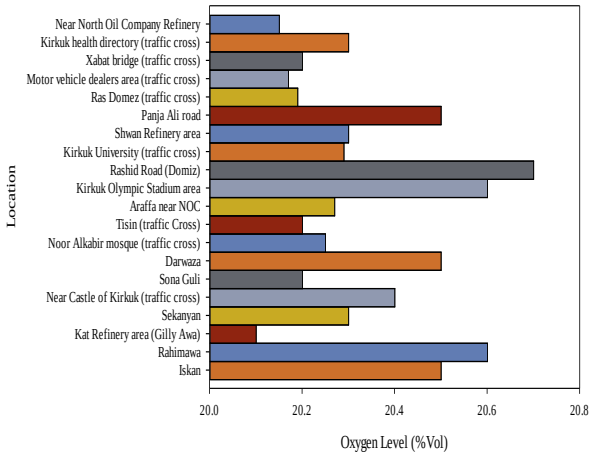


Figure 14. Oxygen Level range at various sites (%Vol)

5. Conclusion

Measuring of TVOCs, HCHO, H_2S, and CO at twenty different sites across Kirkuk city had pointed out some serious pollution issues. The following conclusions had been founded:

1. Measurement of Total Organic Volatile compounds indicated very high pollution level especially near oil industries and traffic crosses, where most sites exceeded the allowable exposure limit 0.5mg/m^3.
2. Although the measured Oxygen level fluctuates from a place to another but still in the safe range from 0 to 0.5mg/m^3, recording a minimum value at the southern part of the city while a maximum at the northeast part of the city.
3. Oil Refineries are the main source of combustible gases detected in Kirkuk outdoor air, where all the measured LEL where at areas near oil refineries, some urban sites have been polluted by oil industry emissions like Araffa and Sekanyan.
4. Measurement of H_2S level indicates the emission of this gas in the areas near oil refineries and it's transmission in air to other parts of the city, where the highest level recorded at northern part due to the closeness of oil refineries while lowest levels were located at the southern part as a result of its far distance from refineries. Sekanyan site has recorded 1.1 ppm which is considered as a high level of H_2S for a living area and it can be easily be detected in that area through its rotten egg odor.
5. The Carbon monoxide emissions have been high in traffic crosses due to the high crowding and a large number of cars passing through traffic areas, this is obvious
6. in the middle and southern part of the city since most traffic crosses are located in that areas.
7. Oil industries are one of the major sources of air pollution in Kirkuk due to the closeness of these industries to residential communities where the gases emitted to the environment and concentrated mostly in the nearby areas.
8. The rate of witnessed development in the city of Kirkuk, especially the frequent purchase of cars led to congestion in the roads, increased pressure on streets, and imbalance in traffic signals, especially at work hours, in addition to a large number of old cars in the city all contributed to the destruction of the urban environment.

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Appendix

Table A1. Concentration of measured air pollutant along Kirkuk city

No.	Locations	O_2 (%VOL)	H_2S (PPM)	TVOC (mg/m^3)	HCHO (mg/m^3)	LEL (%LEL)	CO (PPM)
1	L1	20.5	0.35	0.243	0.079	0	0.4
2	L2	20.6	0.7	0.191	0.045	0	0.5
3	L3	20.1	1.3	1.845	0.157	2.1	1.6
4	L4	20.3	1.1	0.625	0.051	1.3	1.02
5	L5	20.4	0.33	1.104	0.115	0	5.2
6	L6	20.2	0.9	0.753	0.136	0	0.5
7	L7	20.5	0.7	0.689	0.088	0	0.4
8	L8	20.25	0.20	0.929	0.122	0	9.4
9	L9	20.2	0.23	1.179	0.158	0	11.2
10	L10	20.27	0.9	1.108	0.262	0.9	0.97
11	L11	20.6	0.2	0.084	0.035	0	0.3
12	L12	20.7	0.21	0.008	0.055	0	0.4
13	L13	20.29	0.08	0.958	0.090	0	7.6
14	L14	20.3	1.2	2.479	0.288	1.5	1.1
15	L15	20.5	0.3	0.302	0.098	0	1.2
16	L16	20.19	0.25	1.185	0.112	0	6.3
17	L17	20.17	0.22	1.102	0.089	0	5.5
18	L18	20.2	0.4	1.334	0.105	0	7.6
19	L19	20.3	0.095	1.210	0.171	0	5.3
20	L20	20.15	1.5	1.903	0.298	3.9	2