The Environmental Effect of Biogas Concentrations on the City of Baghdad

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Abstract:

The gas emissions emitted from the sewage system have an environmental impact on air pollution with methane gas CH_4 (biogas) in the city of Baghdad and knowing the extent of its impact on the quality of the surrounding air as well as its major role in climate change. The study included measuring the concentrations of methane gas emitted from the sewage system, represented by the three lines transporting sewage in the city of Baghdad (the study area), which are: the Zeppelin line in East Rusafa, the eastern line in West Rusafa, and the third line is the western line in East Karkh, with two locations for each line. This is due to the nature of the semi-closed line design. Therefore, a measurement site was taken for the line from the north near the pumping station to collect sewage water, and a second site for the line was taken from the south near the sewage treatment plants to obtain the most accurate results. The concentrations of biogas were compared with the global determinants to determine the extent of their compliance with the permissible limits. We conclude from this that the concentrations of biogas (CH_4) exceeded the global determinants for collecting the measurement sites and recorded significant pollution in the air surrounding the three lines transporting sewage water, as the highest concentration reached 28.56 ppm at site Z2 and the lowest concentrations were 6.37 ppm at site Z1 for the winter measurement, while the highest and lowest concentrations for the summer measurement reached Respectively 64.01 Z2, 12.01 for site E2 respectively. We conclude from this that the sewage system has an impact on the air pollution of Baghdad city with methane gas (CH_4).

Keywords: Air pollution, biogas, methane, wastewater, environmental impact.

1- Introduction

In the city of Baghdad, there are main pipelines that transport sewage water from pumping stations to treatment plants. The study area includes three main lines: the Zeppelin line in East Rusafa, the eastern line in West Rusafa, and the third line is the western line in East Karkh in the study area. These lines operate in a joint drainage method (rain and sewage) when the water discharge rate in the pipes increases and organic liquid waste increases as it comes from residential areas. Also, if rainfall is rare and in small quantities, as it is feared that the rain network will remain empty without use most days of the year, so the joint working method was adopted to drain sewage and rain together. The flow of sewage in main and branch pipes depends on the speed of its flow in the sewage network (Al-Khazaali, Al-Maliki, 2015). When the speed is slow, solid organic materials will settle, which emit odors resulting from the decomposition of organic materials by anaerobic bacteria (Majid, Abbas, 2018), and thus lead to the emission of methane and other gases and an increase in their concentration during their long passage in the main pipelines, and thus they are exposed to blockage after collecting wastewater, in addition to the negative impact on the surrounding air pollution with biogas, which affects the health of the residents of the area. The accumulation of sediments, grease, fats and other materials in the water of the main sewage pipelines must be eliminated. The Baghdad Municipality has recently used concrete pipes, which are less affected by organic materials in sewage, as well as for their long life and to reduce the problems of street overflow with sewage, especially rain floods in the winter (Al-Jubouri, Al-Mashhadi, 2020). The degree of slope and ruggedness of the land has an effect on determining the location. Suitable for lifting stations and the path of the main pipelines connecting to the treatment plants from both sides of Karkh and Rusafa in the city of Baghdad (Sharif, et al., 2021). The problem of the study is

the high concentrations of methane gas CH4 in the air of the measurement sites and their surroundings in the city of Baghdad, emitted from sewage water. Methane gas is one of the most abundant hydrocarbon compounds composed of carbon and hydrogen in the atmosphere, and it is the most dangerous thermally in the phenomenon of global warming (Abu Al-Naja, 2012). It is a colorless and odorless gas that is slightly soluble in water and lighter than air. Sewage water is an environment rich in biogas, i.e. methane gas, as methane gas constitutes 50-75% of the existing gases. This gas also has the ability to explode even without a source of ignition if it is present in a mixture of 15% in the air and reaches its latent temperature for explosion. It is a highly flammable gas (Al-Saadi, 2002). Therefore, the aim of this study was to identify the sources of methane gas emission into the air in the city of Baghdad, and to know the percentage of gas concentrations in the air of the study area and the extent to which they exceed the internationally permissible limits, as well as to know the risks of methane gas on the environment and health. Previous studies have shown that methane gas is emitted from other sources, such as landfills, as stated in the study (Russell et al., 2022), as well as the study (Areej Al-Rawi, 2013), which showed an estimate of the amount of biogas emitted from sanitary landfill areas in the city of Ramadi. There are also studies that showed the environmental pollution aspect of wastewater and sewage, such as the study (Hana Matar Al-Sultani, 2013), (Muntaka Al-Haidari, 2012), and the study (Ghafran Al-Mahdawi, 2004), among others.

2- Study area

The city of Baghdad is located with its administrative borders on both sides of the Tigris River between altitudes (33 30 – 33. 10) north and longitudes)(44 33 – 44 11) east in a central location in the middle of Iraq. The administrative borders of the Rusafa side of the city of Baghdad are

represented by Diyala Governorate from the north and northeast, and Al-Madain District from the southeast. As for the western side, it is represented by the Tigris River and the municipalities of Al-Kadhimiya, Al-Karkh and Al-Dura. The city of Baghdad includes fourteen municipal units, eight of which are located on the Rusafa side. The area of the study area is (379) km. (Baghdad Municipality, 2017).

3- Method of work

The study included measuring the concentrations of methane gas (CH_4) in the air surrounding the sewage system, emitted from the main pipelines transporting sewage water, represented by three main lines: the Zeppelin line, the eastern line on the Rusafa side, and the western line on the Karkh side, where the biogas (CH_4) was measured using the DX4000Gasmet gas meter, which is a portable device that contains FTIR infrared technology, which is an instant technology for obtaining an infrared spectrum. This technology helps provide immediate and accurate monitoring of many gases, in addition to its flexibility, which helps in using it in many research applications, measurement processes, and monitoring gas emissions. It is currently one of the latest devices in analyzing and monitoring gas emissions, as it gives accurate and high-quality results similar to the fixed Gasmet systems. It is characterized by ease and speed, as well as ease of transportation, so the analyst helps in reducing time and effort. It senses the sample directly through the sensor in it without the need for prior adaptation of the sample and in return gives accurate and direct results. The device measures many of the following gases at the same time: CO_2, N_2O, NO, NO_2, SO_2, HCI, HF, C_2H_6, CH_4, C_2H_4, C_3H_8, CH_2O, CO, etc. As shown in Figure (1) of the Gasmet DX4000 device during the field study.

Figure 1. The Gasmet DX4000 in Action (Captured by the researcher during the summer field study on July 18, 2023).

4-**Main pipelines carrying sewage to treatment plants in Baghdad**

They are a group of pipes with specific diameters buried in the ground at specific depths that transport rainwater and sewage to treatment plants or to rivers. The sewage networks in Baghdad consist of the following: A- Heavy water sewage networks: These are the networks that transport all human and industrial uses of water, such as washing, bathing, cooking, industry, and other different homes and buildings. These waters are polluted with organic and chemical materials, which requires treatment processes.

B- Rainwater sewage networks: These are the networks that transport rainwater collected in the streets and roofs. This water is relatively low in pollution, as the degree of pollution depends on the level of concentration of pollutants present in the streets and roofs. Pollution usually decreases after the first rain

shower, and these rivers are usually collected and thrown directly into the rivers without treatment.

C- Shared sewerage networks: They receive liquid waste from heavy water sewerage networks and part of rainwater, floods and surface water, and the other part of the system transfers the remaining part of rainwater, floods and surface water through specific grooves in the roads that are discharged into the rivers. This type of sewage that was adopted in the city of Baghdad. The main pipelines that transport sewage water to treatment plants consist of a group of sub-pipes that collect water from homes and buildings through the home sewer, which is a pipe that transports waste water from homes and buildings to the sub-pipes (Al-Haidari, 2012), and this water is poured into lines with larger diameters that pass through the main streets and collect water from a group of secondary lines and then transfer it to the main pipeline, as shown in Figure 2.

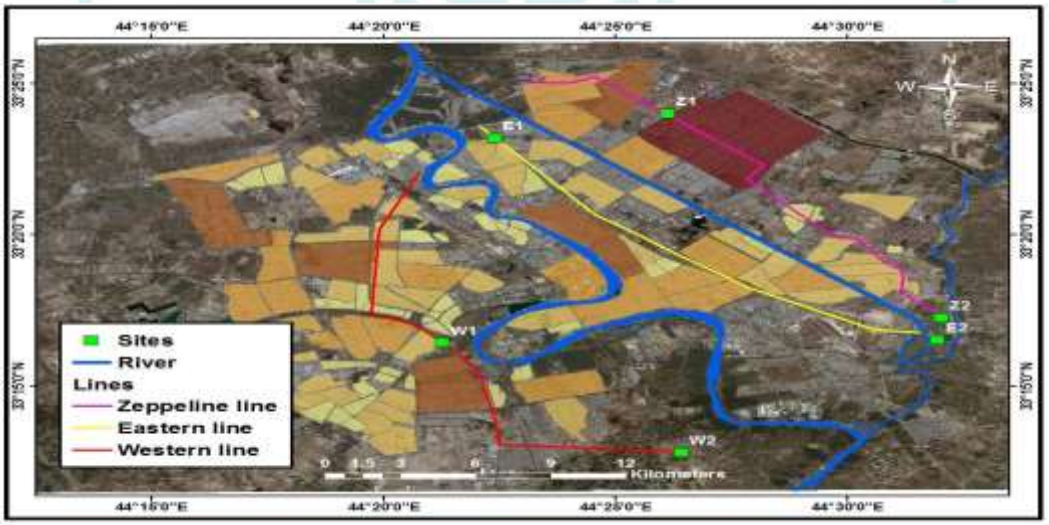

Figure 2. Main Sewage Pipeline Networks Leading to Treatment Facilities in Baghdad (created by the researcher using satellite imagery, utilizing ArcMap software version 10.3.1, 2024).

Lifting pumping stations are established along the collection lines to raise water levels and transfer them to the push lines. These stations are designed to avoid water entering deep depths, as this hinders the maintenance of the networks. The sewage networks in the study area start with branch lines with diameters ranging from 250-600 mm and flow into main lines with diameters of 700 mm and reach 3 meters with vertical and submersible pumping stations. These main lines and pumping stations end at treatment plants represented by the Rustumiyah project on the Rusafa side and the main Karkh project on the Karkh side, then they are released into the river. These are important strategic lines in addressing bottlenecks and the lack of capacity of the current transmission lines, which are three lines in the study area, as follows (Baghdad Municipality, 2022).

A- Eastern Line

This line was implemented in 1961 with a length of 20 km - with a discharge capacity of 6.6 m3/s and diameters ranging from 750-2300 mm starting from the Al-A'dhamiyah area and ending at the old Rustumiyah sewerage project, as it serves the areas of Al-A'dhamiyah, Al-Rusafa Center, Al-Karrada, and the parts located west of the Army Canal for the areas of Al-Ghadeer and New Baghdad (Baghdad Municipality, 2022).

This line starts from the Al-A'dhamiyah area, District 320, with a diameter of 750 mm and reaches Al-Waziriyah station with a diameter of 1100 and then enters the Rustumiyah Municipality with a diameter of 1300 mm within Districts 149, 147, 141, 139, 135 to reach Al-Ghazali station with a diameter of 1600 mm, and continues to flow to the old Rustumiyah project with a diameter of 2300 mm.

Due to the end of the design life of the line, a project was created to rehabilitate it. Approval was obtained to refer the rehabilitation of this project from Al-Ghazali station to Al-Rustamiyah project, where work was returned to a

German company in partnership with two Iraqi companies during 2014, as the Baghdad Sewerage Department is repairing the resulting depressions to avoid delays in drainage (Ali, 2018).

B-Zeppelin Line

The line was implemented in 1980 with a length of 25 km and a discharge capacity of 8.3 m3/second to serve the areas east of the Army Canal with a total area of 5200 hectares. The northern part of the Zeppelin Line starts from the Al-Shaab area and ends at the Al-Habibiya pumping station with diameters of 1800-3000 mm, serving the areas of Al-Shaab - Al-Sadr I and Al-Sadr II in addition to the Al-Rabi and Tunis neighborhoods served by it. As for the southern part, the diameter of the pipe is fixed at 3000 mm, starting from the Al-Habibiya station and ending at the Al-Rustamiya treatment plant - the third expansion to serve part of the areas east of the Army Canal from the Al-Ghadeer and New Baghdad sectors in addition to what the Al-Habibiya sewage station pumps from water coming to it from the northern part of the line. The governing station that connects to this line is Al-Habibiya station, which has 10 pumps and a discharge capacity of 11.5 m3/sec. This line suffers from many problems, including frequent blockages, sediments, and violations, and its inability to accommodate the increase in water supply due to the large population increase and the expansion of the areas it serves. The Baghdad Sewerage Department cleaned the sewer line on the Rusafa side, the Zeppelin line extending from Al-Habibiya station to the Rustumiya Treatment Plant - the third expansion. As for referring the second part of the Zeppelin line, which represents the suction line that starts from the Al-Shaab area to Al-Habibiya station.

C - Western Line

The line was implemented in 1980 and the length of the western transmission line is about 22,500 meters. It is the only transmission line on the Karkh side of

Baghdad. It starts from Abdul Mohsen Al-Kadhimi RQ station in the center of Al-Kadhimiya district, passing through the Al-Shu'la, Al-Mansour, Al-Rasheed and Al-Dura areas and ends at the main Karkh treatment plant in Al-Buaitha, south of Baghdad. The diameters of the line range between 1400 - 3000 mm, as the line starts from Abdul Mohsen Al-Kadhimi station with two double lines with a diameter of 1400 mm and a depth of 2 - 6 meters and a discharge capacity of 3500 liters / second. The diameter of the line becomes 2400 mm, where a main line with a diameter of 1700 mm is connected to it with a discharge capacity of 2600 liters / second. Before the line enters the Al-Qadisiyah station with a diameter of 3000 mm and a depth of 7 - 10 meters, the Al-Bayaa station push line is connected to it, which is also 3000 mm in diameter and has a discharge capacity of 8700 liters / second. The western line comes out from Al-Qadisiyah station with a diameter of 3000 meters to be pumped to Al-Saydiyah PN station with a diameter of 2500 mm and a discharge capacity of 6000 liters/second. The line ends at Al-Dura station with a diameter of 3000 mm and a depth of 6-7 meters. Al-Dura station is connected by three 3 x 1600 mm push lines to Al-Karkh treatment plant. The number of inspection basins on the western line is 152 basins (Baghdad Municipality, 2022).

5- **Results of measuring the concentrations of methane gas (biogas) emitted from the main pipelines transporting sewage to treatment plants in the city of Baghdad**.

The study included measuring the concentrations of methane gas in the air and emitted from the sewage system, represented by the three main lines that transmit it, as it results from the biological decomposition by microscopic organisms present in sewage, as the decomposition of organic materials in the sewage system increases with the absence of free oxygen and under temperatures that cause the release of gases with an unpleasant odor represented by hydrogen sulfide gas (H_2S), methane (CH_4), carbon monoxide

gas (CO), and carbon dioxide gas (CO_2). Some of these gases are toxic, especially hydrogen sulfide gas (H_2S), whose toxicity is tens of times greater than that of carbon monoxide gas (CO). The dangers of this gas are that the higher its concentration, the more the ability to sense it through smell is lost, as the limits for sensing the smell of H_2S gas in humans are between (0.002 - 1) parts per million (Lucy, 2012). The presence of gases with an unpleasant odor in the air in quantities that are not permitted It leads to an increase in the concentration of air pollutants, and this pollution constitutes the most dangerous environmental pollution due to its easy spread from one area to another in a short period of time. One of the most important effects of pollution is that the unsuitable air quality affects human health and leads to the killing of many living organisms, including humans. Air quality is usually determined based on measuring gaseous pollutants emitted from the sewage system. The study area recorded significant methane (CH_4) pollution that exceeded global limits in the air surrounding the sewage system, as shown in Table 1.

Table 1. Methane Gas Concentrations Emitted from the Sewage Water System for Winter and Summer Measurements in the Study Area.

Main Line	Site Code	Measurement Location	Winter Measurement (ppm)	Summer Measurement (ppm)	Average (ppm)	WHO Standard Compliance
Zablen / West Rusafa	Z1	Al-Habibiya	6.37	33.84	20.10	Exceeded
	Z2	New Baghdad	28.56	64.01	46.28	Exceeded
Eastern / East Rusafa	E1	Al-Azamiyah	25.94	18.59	22.26	Exceeded
	E2	Al-Rustamiyah	28.52	12.01	20.26	Exceeded
Western /	W1	Al-Qadisiyah	10.66	19.18	14.92	Exceeded

West Karkh	W2	Dora (Al-Bu'aitha)	14.90	12.40	13.65	Exceeded

The highest concentration was (28.56) ppm at site Z2 and the lowest concentration was 6.37 ppm at site Z1 for the winter measurement, while the highest and lowest concentrations for the summer measurement were 64.01, 12.01 for site Z2, E2 respectively. We conclude from this that the sewage system has an impact on the air pollution of Baghdad city with methane gas (CH_4), as shown in Figure 3. We find that most of the measurement sites for the main lines carrying sewage water in the city of Baghdad have exceeded the permissible limits. The reason for the increase in methane gas concentrations is that the place is semi-exposed and wide, as climatic factors, especially winds, lead to the dispersion of this gas, in addition to large quantities of organic compounds and large numbers of aerobic and anaerobic microorganisms. These organisms affect organic and inorganic compounds, causing a shortage of oxygen (Hashem, 2007). In the absence of oxygen, methane gas is produced by converting organic carbon into methane gas (Al-Sultani, 2013).

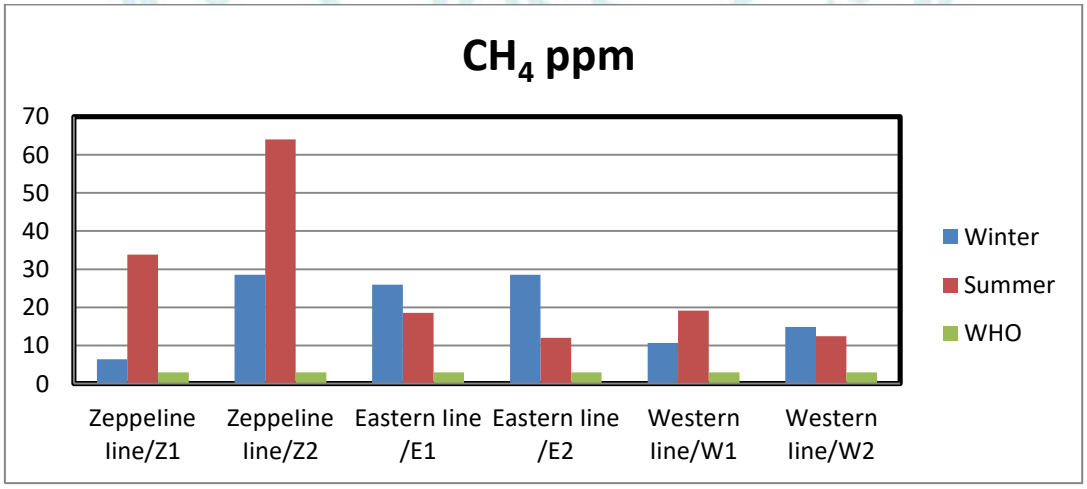

Figure 3. Methane Gas Concentrations Emitted from the Sewage Water System During Winter and Summer Measurements in the Study Area

We note from Table 2 the results of the winter measurement of methane gas, that its highest concentration reached 28.56 ppm in the Zeppelin line on the Rusafa side of site Z2 in the New Baghdad area, and its lowest concentration was for the same Zeppelin line of site Z1 in the Al-Habibiya area, which recorded 6.37 ppm, as the high amount of gas in the Zeppelin line of site Z2 is due to the wastewater that contains a large amount of organic compounds and large numbers of aerobic and anaerobic microorganisms. These organisms affect the organic and inorganic compounds, causing a deficiency in oxygen (Hashem, 2007). In the absence of oxygen, methane gas is produced by converting organic carbon into methane gas, and through this process (oxidation), up to 60% of the biological oxygen requirement BOD is removed (Al-Sultani, 2013). See Figure 4, which shows the spatial analysis of methane gas concentrations (CH_4) ppm in the wastewater system of the study area for winter measurement.

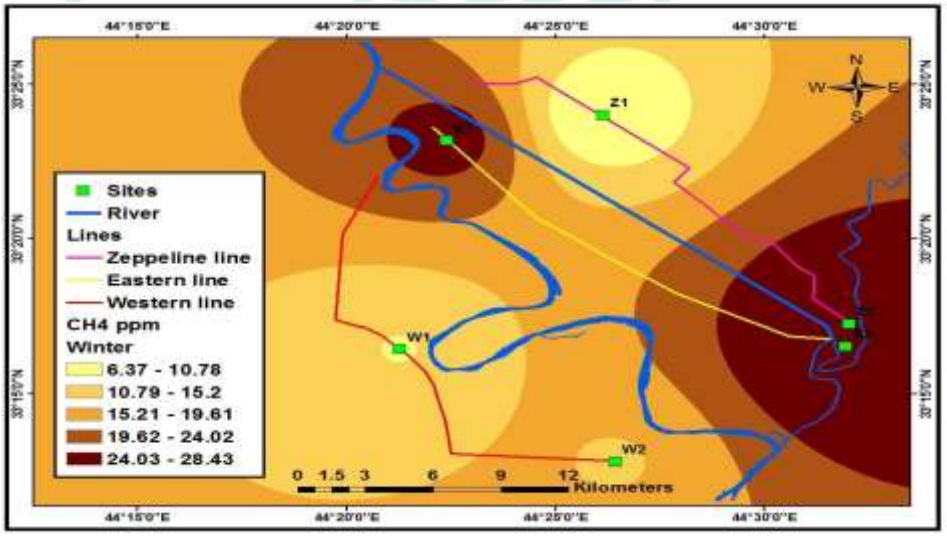

Figure 4. Spatial Analysis of Methane (CH_4) Concentrations in the Sewage Water System of the Study Area for Winter Measurement (Created by the researcher using satellite visuals, utilizing ArcMap software version 10.3.1, 2024).

The results of the summer measurement of methane gas, as shown in Table 3, showed that its concentration reached 64.01 ppm for site Z2 in the New Baghdad area, and its lowest concentration was in the Rustumiya area for site E2, which reached 12.01 ppm. The high concentrations of gas in the area are due to many reasons, including the high temperatures in the summer, as well as the presence of organic waste in the sewage water as it comes from residential areas that anaerobic bacteria decompose by generating many gases, most of which is methane gas, and thus leads to the emission of methane gas and an increase in its concentrations. In addition, the direction and speed of the prevailing northwesterly winds in the study area play a major role in spreading gaseous pollutants emitted from the sewage system, which carries pollutants to long distances. See Figure 5, which shows the spatial analysis of methane gas (CH_4) ppm concentrations in the sewage system of the study area for summer measurement.

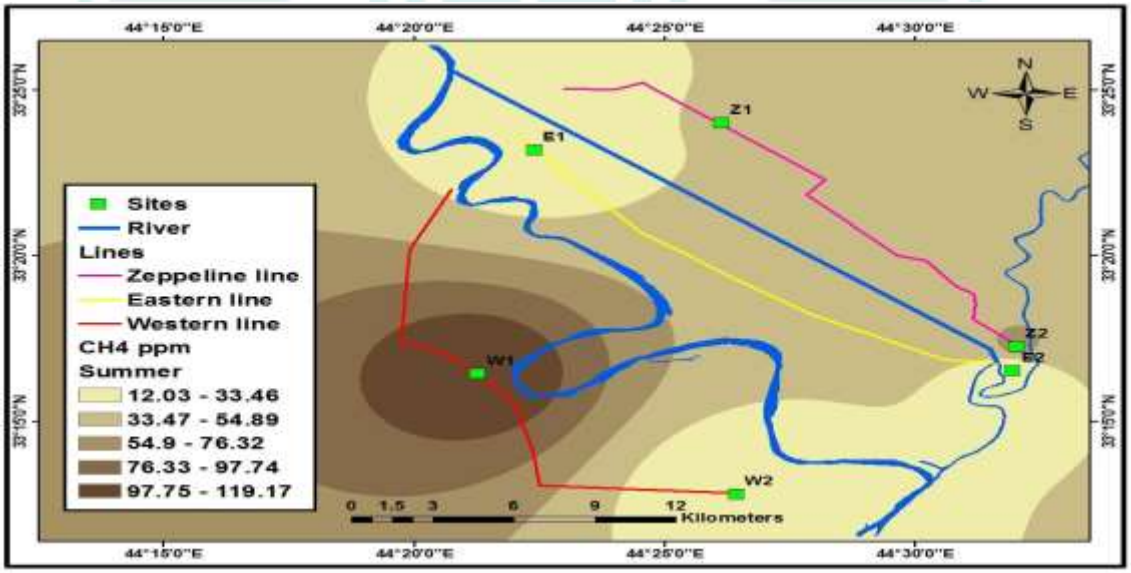

Figure 5. Spatial Analysis of Methane (CH_4) Concentrations in the Sewage Water System of the Study Area for Summer Measurement (Created by the researcher using satellite imagery, utilizing ArcMap software version 10.3.1, 2024).

6- Environmental impact of methane gas (CH_4)

A- Methane gas and global warming

Methane gas is an important greenhouse gas despite its low percentage in the atmosphere compared to carbon dioxide. The importance of this gas stems from the fact that it absorbs the rays emitted by the Earth in a spectral band in which there is no significant absorption (atmospheric window) by other gases, specifically water vapor and carbon dioxide. The percentage of methane gas is about 1.72 parts per million, and the percentage of methane increases in the northern hemisphere compared to the southern hemisphere. Various studies have shown that methane gas is steadily increasing in the atmosphere (Al-Aroud, 2001), and 4-9% of the manifestations of global warming are attributed to this gas. Methane gas is produced from wastewater treatment plants, and is also produced from the analysis of organic elements by bacteria, especially in wastewater collection sites that contain biological waste. Methane gas has a thermal absorption capacity that exceeds the capacity of CO2 gas by about (20-30) times, but fortunately it is found in a lower concentration in the atmosphere (Abu Diya, 2012).

B- Health effects of methane gas facing workers in the wastewater system

As is known, these places contain dirty and rotten water, so workers in this system face multiple dangers that affect the body, especially the digestive system and the respiratory system, as a result of daily exposure to toxic and suffocating gases in varying doses, such as methane gas (CH_4). This gas has very dangerous effects on human health. Previous deaths have occurred in the wastewater system as a result of exposure to methane gas (CH_4) in closed spaces, which makes it displace air and replace it because it is heavier than air. Therefore, it may expose humans or other living organisms to death due to lack of oxygen, which leads to suffocation in such conditions. There is also another danger inherent in this gas through its ability to explode even without an

ignition source if it is present in a mixture of 15% in the air and reaches its latent temperature for explosion (Al-Saadi, 2002). In addition to that, skin diseases that affect workers as a result of exposure and direct contact with dirty water. This illustrates the process of cleaning the sewage system basin, where we find that cleaning workers work without providing any safety requirements at work sites such as equipment such as face masks to protect workers from deadly gases, as well as gloves, masks, shoes and clothing that protect against sewage waste.

7-Conclusions:

The research reached through field measurements of biogas emissions (CH_4) represented in six sites distributed over the three sewage transmission lines: the Zeppelin line in East Rusafa, the eastern line in West Rusafa, and the third line is the western line in East Karkh in the study area, with two sites for each line, due to the nature of the semi-closed line design, so a measurement site was taken for the line from the north near the pumping station to collect sewage water and a measurement site for the line in the south near the sewage treatment plants to obtain the most accurate results, and the concentrations of biogas were compared with the global determinants to determine the extent of their compliance with the permissible limits. We conclude from this that the concentrations of biogas (CH4) exceeded the global determinants for collecting the measurement sites and recorded significant pollution in the ambient air of the sewage system, as the highest concentration reached 28.56 ppm at site Z2 and the lowest concentrations 6.37 ppm at site Z1 for the winter measurement, while the highest and lowest concentrations for the summer measurement reached, respectively 64.01, 12.01 for sites Z2, E2 respectively. We conclude from this that the sewage system has an impact on the air pollution of Baghdad city with methane gas (CH_4).

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