زانکۆی سەلاحەدین - هەولێر
Salahaddin University-Erbil

Air Quality Assessment in Erbil city, Kurdistan Region of Iraq.

Research Project

Submitted to the Department of (Biology) in partial fulfillment of the requirements for the degree of **BSc.** in **Biology**

By

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CERTIFICATE

This research project has been written under my supervision and has been submitted to the department of biology for the award of the degree of **BSc.** in **Biology** with my approval as a supervisor.

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DEDICATION

This effort I dedicate to **Allah** Almighty, my lord, my powerful foundation, my source of inspiration, wisdom, knowledge, and understanding. Throughout this project, he was the source of my energy.

Rayan

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To begin with, I thank (Allah) for His blessing, which made me able to complete and perform this study with success, the lord of the universe, blessing, and peace be on Muhammad (Allah's peace and prayers be upon him).

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ABSTRACT

Air pollution is a major problem all over the world in both developed and developing countries. Rapid increase in population and demand for energy have resulted in emission of toxic air pollutants that affect the surrounding environment as well as human health. Pollution, especially pollution caused by industrial emissions, large and private power generators, vehicular exhausts, and toxic chemicals, has increased sharply in the past 200 years, and the largest increases today are seen in low-income and middle-income countries. In the present study, the mean value of HCOH levels were higher than WHO-Ambient Air Quality standards (AAQS) and exceeded 0.050 mg/m3 during the study period. The minimum value of 0.004 (mg/m3) was recorded at Regay Masif-Kurdnaft site while the maximum value of 0.504 (mg/m3) was recorded at Regay Masif-Naxoshkhanay Komary and Setaqan-Naxoshkhanay Rzgary during the first and second sampling period respectively. It is clear that high Formaldehyde concentration was found inside 30m circle (Baghy Shar, Mzgawty Choly and Parky Shanadar), while sites that located inside 100m and 120m circles were characterized by low levels of formaldehyde.

During the study period, the mean values of TVOC were lower than the maximum permission level of 5 (mg/m^3) at all sampling periods and in all sites. The minimum concentration of 0.05 (mg/m^3) was recorded at Mzgawty Choly during the 3rd sampling period while the maximum level of 3.779 (mg/m^3) was measured at Regay Masif-Naxoshkhanay Komary during the 1st sampling period. Particulate Matter with diameters of 2.5 micrometers or less-$PM_{2.5}$ were high during the whole study period and exceeded the maximum permission value of 15 ($\mu g/m^3$) in almost all sites. Carbone dioxide concentrations were higher than AQS (>1000ppm) during the whole period of this study. The minimum value of 854 (ppm) was recorded at Regay Masif-Kurdnaft during the first sapling period while the maximum value of 1358 (ppm) was recorded at Regay Masif-Naxoshkhanay Komary during the same period.

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Abbreviations	Definitions
AQI	Air Quality Index
AQS	Air Quality Standards
CO	Carbon Monoxide
CO_2	Carbon Dioxide
HCOH	Formaldehyde
ICI	International Corruption Index
IEO	International Energy Outlook
KRI	Kurdistan Region of Iraq
NO_x	Nitrogen Oxides
PM_{10}	Particulate matter with diameter of 10 microns or less.
$PM_{2.5}$	Particulate matter with diameter of 2.5 microns or less.
SO_x	Sulfur Oxides
TVOC	Total Volatile Organic Compounds

1. INTRODUCTION

Air pollution has important implications on the ecological environment (Wang et al., 2016), and could also destroy vegetation and monuments (Brook et al., 2004,). Air pollution is a very significant environmental and social issue. At the same time, it is a complex problem posing multiple challenges in terms of management and mitigation of harmful pollutants. Air pollutants have numerous impacts on health, ecosystems, built environment and climate; they may be transported or formed over long distances, and they may affect large areas. One of the main constituents of air pollution is fine particulate matter ($PM_{2.5}$) (Guo *et al*., 2014). $PM_{2.5}$ consists of airborne particles with aerodynamic diameters less than 2.5 μm. They are known to adversely affect human health (Pope *et al*., 2009] and potentially have lasting negative effects on agriculture (Burney and Ramanathan, 2014), climate, ecosystem, and many aspects of society (Wang *et al*., 2014; Prajapati, 2012; Zhao *et al*., 2013).

The direct and indirect adverse effects caused by atmospheric pollution on the environment and human health necessitate the measurement and reporting of air quality on local, regional and global scales. The measurement and improvement of air quality in developed countries are considered a priority. In developing countries less emphasis is placed on environmental issues, because resources are mostly utilized for economic growth. Many countries, especially developing countries, suffer from air pollution. In recent years, significant research has been conducted on air quality monitoring and evaluation systems. The research can be divided into air quality assessment and air pollutants forecasting.

In the areas not affected by industrial activities or human settlements, farming activities are still practiced. Environmental monitoring and early warning is the basic function of environmental protection work, not only in relation to scientific decision-making, but also long-term development.

Petroleum refineries are vital to the production of the fuels that people rely on for transportation, heating, and other activities. Refineries continually seek to improve efficiency of operations and to reduce environmental impacts (Nelson, 2013).

With the use of fossil fuels, new problems arose as evidence suggested that the processes of the extraction, refinement, storage, transportation and combustion of oil and its derivatives caused major global problems, such as the greenhouse effect, depletion of the ozone layer as well as acid rain and pollution. In addition to representing a problem to the environment, it ultimately poses a great danger to life on our planet due to the damage that it causes to the health of entire populations and ecosystems. For example, human health effects can result from consuming contaminated food or by bathing in polluted water mainly of rivers (Gower, *et al*., 2008).

Contaminants associated with the extraction of crude oil exploitation involves operational steps including exploration, extraction, refinement, and transportation. Extraction is responsible for bringing natural hydrocarbons (e.g., crude oil) to the surface; for this activity, there are several methods (e.g., mechanical pumping, hydraulic pumping, and use of acids). All of these processes produce serious environmental damage, including deforestation and pollution in the air, water, and soil (Ramirez, *et al*., 2017).

The aim of our project it to evaluate the air quality of Erbil, KRI using the ambient Air Quality parameters such as formaldehyde, TVOC, particulate matter and carbon dioxide.

2. LITERATURE REVIEWS

(Rourke and Connolly, 2003) presents existing data and research on the global distribution of the impacts of oil production and consumption. The review describes and analyzes the environmental, social, and health impacts of oil extraction, transport, refining, and consumption, with a particular focus on the distribution of these burdens among socioeconomic and ethnic groups, communities, countries, and ecosystems. An environmental justice framework is used to analyze the processes influencing the distribution of harmful effects from oil production and use. A critical evaluation of current research and recommendations for future data collection and analysis on the distributional and procedural impacts of oil production and consumption conclude the review (Polvara, *et al*., 2021).

(Ramis, 2012) explained that emissions from refineries include a wide range of substances, such as chrome, lead, nickel, zinc, arsenic, cadmium, benzene, dioxins and furans, all of which are recognized by the International Agency for Research on Cancer (IARC) as carcinogens. Various studies have shown an association between non-Hodgkin lymphoma (NHL) and residence in the vicinity of industrial areas; however, evidence of specific association between refineries and residence in the vicinity has been suggested but not yet established. The aim of this study is to investigate potential links between environmental exposure to emissions from refineries and non-Hodgkin lymphoma mortality in Spain. The spatial distribution of NHL in Spain has an unusual pattern with regions some showing higher risk than others.

(Myasnikova *et al*., 2019) analyze the problem of the complexity in managing of the environmental safety of an oil refinery. The possibility of using environmental monitoring methods for integrated regulation and the formation of optimal control parameters is noted. It's based on the principles of combining efficient production processes with environmental programs, which will be promotive of the production output with the technogenic impact minimization of oil refining technology on the environment.

(Onyije *et al*., 2021) evaluated the cancer risk in petroleum-exposed workers and in residents living near petroleum facilities. Relevant studies were identified and retrieved through PubMed and Web of Science databases. Summary effect size (ES) and 95% confidence intervals (CI) were analyzed using random effect models, and heterogeneity across studies was assessed (I2). Overall, petroleum industry work was associated with an increased risk of mesothelioma (ES = 2.09, CI: 1.58–2.76), skin melanoma (ES = 1.34, CI: 1.06–1.70 multiple myeloma (ES =1.81, CI: 1.28–2.55), and cancers of the prostate (ES = 1.13, Cl: 1.05–1.22) and urinary bladder (ES = 1.25, CI: 1.09–1.43) and a decreased risk of cancers of the esophagus, stomach, colon, rectum, and pancreas. Offshore petroleum work was associated with an increased risk of lung cancer (ES = 1.20; 95% CI: 1.03–1.39) and leukemia (ES = 1.47; 95% CI: 1.12–1.92) in stratified analysis. Residential proximity to petroleum facilities was associated with childhood leukemia (ES = 1.90, CI: 1.34–2.70). Very few studies examined specific exposures among petroleum industry workers or residents living in oil producing communities. The present review warrants further studies on specific exposure levels and pathways among petroleum-exposed Workers and residents living near petroleum facilities.

(Sharma *et al*.,2021) demonstrated the co-hydrodeoxygenation of partially upgraded bio-oil (PUB) obtained from hydrothermal liquefaction of pinewood, with rapeseed oil (RO) to produce bio-derived drop-in fuel. Enhanced miscibility of PUB in RO showed the high potential of HTL bio-oil for co-processing with different refinery streams in existing refineries. Co-processing experiments were conducted in a continuous unit under different processing conditions and the obtained results were compared with the hydroprocessed oils produced from the pure RO. Temperature and weight hourly space velocity (WHSV) are found to be important parameters to achieve complete deoxygenation and controlling the properties of co-processed bio-oils. Product quality analysis of co-processed bio-oils obtained under optimized conditions showed no oxygen contents and micro carbon residue but high n-paraffins. Furthermore, boiling point distribution of co-processed bio-oils was measured by SimDis, which was found analogous to boiling range of biodiesel.

Fuel characteristic properties such as flash point, pour and cloud points of co-processed bio-oils were also measured and found improved compared to the properties of hydroprocessed oil obtained from RO. Therefore, this study demonstrates that HTL bio-oil can be successfully co-processed with renewable feed and petroleum refinery streams in a continuous hydroprocessing unit without any modification to reduce the environmental impacts and overcome the cost, availability and sustainability issues of oleochemical based feedstocks.

The population of the KRI has more than doubled in the last two decades, rising from 3 million in 1997 to approximately 7.2 in 2019 which makes the KRI population intensity (177 people/km^2) more than twice that of the population intensity in the rest of Iraq (83 people/km^2). These figures are also found to be higher than those of the neighboring countries. Iran's population, for instance, increased in the last two decades by approximately 25%, from 65.9 million to 82.1 million, and its population density in 2020 is 52 people/km^2. Similarly, Turkey's population rose by 25% from 66.4 million to 83.1 with a population density of 110 people/km^2. This recent increase in population is attributed to the natural migration from rural to urban centers, forced migration, and international immigration. The current stability in the region is attracting businesses, creating jobs, and stimulating international immigration into the cities. The rise in population has been increasingly worsening the environmental problems in the KRI through consuming utilities, food, and water, using urban transport, and generating more waste (Hawkare, 2021).

3.Materials and Methods:

3.1. Description of sampling sites:

Sixteen sampling sites were selected in Erbil city as follows: Four sites (1-4) (Shaqamy Pzishkan, Barrewabaraiaty Parwada, Baghy Shar and Mzgawty Choly) were selected inside 30m circle. Another four sites (5-8) (Regay Ainkawa (30-60m), Ragay Masif-Naxoshkhanay Komary, Setaqan-Mzgawti Said Gharib and Parky Shanadar) were selected inside 60m circle. Another four sites (9-12) (Regay Ainkawa (60-100m), Ragay Masif-Shorsh Market, Setaqan-Naxoshkhanay Rzgary and Regay Makhmur) were selected inside 100m circle. Finally, another four sites (13-16) (Regay Ainkawa (100-120m), Ragay Masif-Kurdnaft, Regay Koya, Rasuly Taibat and Pishasazy Bashur) were selected inside 120m circle. Air Quality parameters were recorded during three different sampling periods on 13-14 October 2022, 23-24 October 2022 and 18 December 2022.

3.2. Air quality gas analysis:

Five air quality gases were obtained by (Multifunctional Air Gas Detector Real Time, Model: JJG1022) as follow:

Formaldehyde-HCHO (mg/m^3), Total Volatile Organic Compound -TVOC (mg/m^3), Particulate Matter that is 2.5 micron or smaller in size- $PM_{2.5}$ ($\mu g/m^3$), Particulate Matter that is 10 micron or smaller in size-PM_{10} ($\mu g/m^3$) and carbon dioxide-CO_2 (ppm).

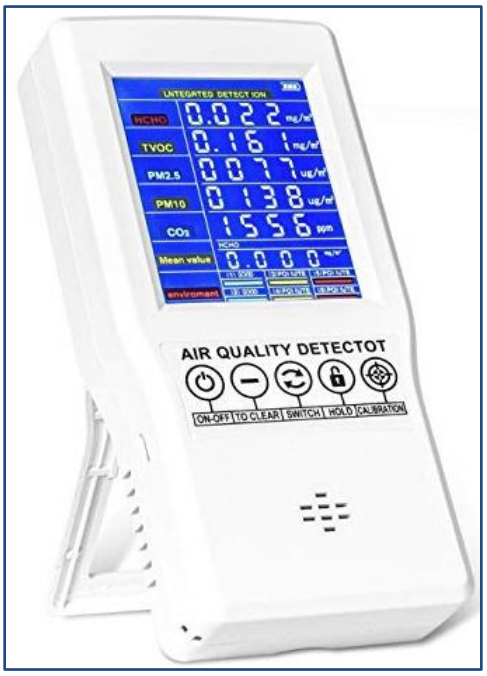

Figure 1. Multifunctional Air Gas Detector Real Time, Model: JJG1022.

4.Results and Discussions

4.1. Formaldehyde-HCOH: Formaldehyde (HCHO) is the most important carcinogen in outdoor air among the 187 hazardous air pollutants (HAPs) identified by the U.S. Environmental Protection Agency (EPA). Formaldehyde is a simple organic compound that consists of a carbonyl group (C=O) attached to a hydrogen atom. Formaldehyde is highly reactive and is used in the production of various chemicals and materials, including resins, plastics, and textiles. It is also used as a disinfectant and preservative in medical and laboratory settings. However, exposure to formaldehyde can be harmful to human health and has been linked to respiratory problems, cancer, and other health issues.

According to Table 1, the mean value of HCOH levels were higher than WHO-Ambient Air Quality standards (AAQS) and exceeded 0.050 mg/m^3 during the study period. The minimum value of 0.004 (mg/m^3) was recorded at Regay Masif-Kurdnaft site while the maximum value of 0.504 (mg/m^3) was recorded at Regay Masif-Naxoshkhanay Komary and Setaqan-Naxoshkhanay Rzgary during the first and second sampling period respectively. It is clear that high Formaldehyde concentration was found inside 30m circle (Baghy Shar, Mzgawty Choly and Parky Shanadar), while sites that located inside 100m and 120m circles were characterized by low levels of formaldehyde.

Exposure to formaldehyde can have adverse health effects. The extent of the health effects depends on the level and duration of exposure. Some of the health effects associated with formaldehyde exposure include: Respiratory problems, Eye, nose, and throat irritation, Skin irritation, Allergic reactions, Cancer; because Formaldehyde has been classified as a human carcinogen by the International Agency for Research on Cancer (IARC) and has been linked to cancer of the nasal cavity, throat, and lungs.

Table 1. Formaldehyde (HCHO) concentration (mg/m^3) recorded at three sampling date during the study period, with WHO-Ambient Air Quality standards (WHO, 2022).

Sites	HCHO (mg/m^3) 1st Sampling	HCHO (mg/m^3) 2nd Sampling	HCHO (mg/m^3) 3rd Sampling
Shaqamy Pzishkan	0.041	**0.079**	0.021
Barrewabaraiaty Parwada	0.035	0.022	0.036
Baghy Shar	**0.121**	0.018	**0.076**
Mzgawty Choly	**0.173**	**0.095**	0.007
Regay Ainkawa (30-60m)	**0.132**	**0.097**	0.035
Ragay Masif-Naxoshkhanay Komary	**0.504**	0.037	0.027
Setaqan-Mzgawti Said Gharib	**0.230**	**0.294**	**0.201**
Parky Shanadar	0.033	0.007	0.013
Regay Ainkawa (60-100m)	**0.184**	**0.079**	0.041
Ragay Masif-Shorsh Market	**0.113**	**0.101**	**0.244**
Setaqan-Naxoshkhanay Rzgary	**0.074**	**0.378**	0.032
Regay Makhmur	0.021	0.021	**0.262**
Regay Ainkawa (100-120m)	**0.081**	**0.109**	**0.084**
Ragay Masif-Kurdnaft	0.004	0.031	**0.297**
Regay Koya, Rasuly Taibat	**0.330**	**0.106**	**0.123**
Pishasazy Bashur	0.016	**0.298**	**0.277**
Mean	**0.131**	**0.111**	**0.111**
WHO-Air Quality Standards-AQS	0.050	0.050	0.050

4.2. Total Volatile Organic Compounds-TVOC: Total Volatile Organic Compounds (TVOC) is a term used to describe a group of organic chemicals that can easily evaporate at room temperature. These chemicals can be found in many products and materials, including paints, adhesives, cleaning agents, and building materials. When present in air, TVOCs can contribute to poor air quality and can have adverse health effects.

During the study period, the mean values of TVOC were lower than the maximum permission level of 5 (mg/m^3) at all sampling periods and in all sites. The minimum concentration of 0.05 (mg/m^3) was recorded at Mzgawty Choly during the 3rd sampling period while the maximum level of 3.779 (mg/m^3) was measured at Regay Masif-Naxoshkhanay Komary during the 1st sampling period.

Exposure to TVOCs can cause a range of health effects, depending on the level and duration of exposure. Some of the health effects associated with TVOC exposure include: Eye, nose, and throat irritation: TVOCs can irritate the eyes, nose, and throat, leading to burning, itching, and soreness. Headaches: Exposure to TVOCs can cause headaches and migraines. Dizziness: TVOC exposure can cause dizziness, lightheadedness, and nausea. Respiratory problems: TVOCs can irritate the respiratory tract, causing coughing, wheezing, and shortness of breath. It is important to limit exposure to TVOCs to reduce the risk of these health effects. This can be done by using products that are low in TVOCs, increasing ventilation, and avoiding smoking and other sources of indoor air pollution.

Table 2. Total Volatile Organic Compounds-TVOC concentration (mg/m^3) recorded at three sampling date during the study period, with WHO-Ambient Air Quality standards (WHO, 2022).

Sites	TVOC (mg/m^3) 1st Sampling	TVOC (mg/m^3) 2nd Sampling	TVOC (mg/m^3) 3rd Sampling
Shaqamy Pzishkan	**0.283**	**0.713**	**0.136**
Barrewabaraiaty Parwada	**0.220**	**0.159**	**0.151**
Baghy Shar	**0.797**	**0.133**	**0.523**
Mzgawty Choly	**1.650**	**0.989**	0.050
Regay Ainkawa (30-60m)	**0.876**	**0.590**	**0.195**
Ragay Masif-Naxoshkhanay Komary	**3.779**	**0.240**	**0.239**
Setaqan-Mzgawti Said Gharib	**2.225**	**0.124**	**1.546**
Parky Shanadar	**0.235**	**0.053**	**0.074**
Regay Ainkawa (60-100m)	**1.402**	**0.729**	**0.203**
Ragay Masif-Shorsh Market	**0.775**	**1.022**	**1.516**
Setaqan-Naxoshkhanay Rzgary	**0.712**	**1.975**	**0.308**
Regay Makhmur	**0.128**	**0.128**	**1.789**
Regay Ainkawa (100-120m)	**0.560**	**0.938**	**0.494**
Ragay Masif-Kurdnaft	0.030	**0.259**	**2.387**
Regay Koya, Rasuly Taibat	**0.246**	**0.946**	**0.919**
Pishasazy Bashur	0.078	**2.018**	**2.189**
Mean	**0.875**	**0.689**	**0.795**
WHO-Air Quality Standards-AQS	5	5	5

4.3. $PM_{2.5}$: $PM_{2.5}$ refers to particulate matter that is 2.5 micrometers or smaller in diameter. These tiny particles can be found in indoor and outdoor environments and can have adverse health effects when inhaled. $PM_{2.5}$ can come from a variety of sources, both natural and human-made. Some common sources of $PM_{2.5}$ include: Wildfires: Smoke from wildfires can contain high levels of $PM_{2.5}$. Transportation: Exhaust from cars, trucks, and other vehicles can contain $PM_{2.5}$. Industrial sources: Industrial processes, such as manufacturing and construction, can release $PM_{2.5}$ into the air. Burning of fossil fuels: Burning of fossil fuels, such as coal and oil, can release $PM_{2.5}$ into the air. Tobacco smoke: Tobacco smoke contains $PM_{2.5}$, which can be inhaled by both smokers and non-smokers.

Particulate Matter with diameters of 2.5 micrometers or less-$PM_{2.5}$ were high during the whole study period and exceeded the maximum permission value of 15 ($\mu g/m^3$) in almost all sites. The minimum value of 4 ($\mu g/m^3$) was measured at site Parky Shanadar during the 3rd sampling period whereas the maximum value of 89 ($\mu g/m^3$) recorded at Regay Ainkawa (60-100m) during the 1st sampling period of the study. On the other hand, the mean value for all sites during the whole study period was exceeded the maximum permission level of 15 ($\mu g/m^3$). These results indicate polluted air by $PM_{2.5}$ in Erbil city.

Exposure to $PM_{2.5}$ can have a range of health effects, depending on the level and duration of exposure. Some of the health effects associated with $PM_{2.5}$ exposure include: Respiratory problems: $PM_{2.5}$ can irritate the respiratory tract, causing coughing, wheezing, and shortness of breath. Cardiovascular problems: Exposure to $PM_{2.5}$ has been linked to an increased risk of heart disease and stroke. Asthma: Exposure to $PM_{2.5}$ can aggravate asthma symptoms. Allergic reactions: Some people may develop an allergic reaction to $PM_{2.5}$, which can cause symptoms such as hives, itching, and difficulty breathing. Lung cancer: Long-term exposure to $PM_{2.5}$ has been associated with an increased risk of lung cancer. It is important to limit exposure to $PM_{2.5}$ to reduce the risk of these health effects.

Table 3. $PM_{2.5}$ concentration ($\mu g/m^3$) recorded at three sampling date during the study period, with WHO-Ambient Air Quality standards (WHO, 2022).

Sites	$PM_{2.5}$ ($\mu g/m^3$) 1st Sampling	$PM_{2.5}$ ($\mu g/m^3$) 2nd Sampling	$PM_{2.5}$ ($\mu g/m^3$) 3rd Sampling
Shaqamy Pzishkan	**24**	**42**	11
Barrewabaraiaty Parwada	**32**	**20**	**16**
Baghy Shar	**27**	**23**	5
Mzgawty Choly	**33**	**23**	**16**
Regay Ainkawa (30-60m)	**24**	**17**	**17**
Ragay Masif-Naxoshkhanay Komary	**35**	**23**	**17**
Setaqan-Mzgawti Said Gharib	**25**	**23**	**22**
Parky Shanadar	17	**36**	4
Regay Ainkawa (60-100m)	**89**	**18**	**23**
Ragay Masif-Shorsh Market	**47**	15	**18**
Setaqan-Naxoshkhanay Rzgary	**22**	**22**	**23**
Regay Makhmur	**37**	**37**	**28**
Regay Ainkawa (100-120m)	**23**	**22**	**27**
Ragay Masif-Kurdnaft	**31**	15	**43**
Regay Koya, Rasuly Taibat	**26**	15	**21**
Pishasazy Bashur	**59**	63	76
Mean	**34.438**	**25.875**	**22.378**
WHO-Air Quality Standards-AQS	15	15	15

4.4. PM_{10}: PM_{10} refers to particulate matter with a diameter of 10 micrometers or less. These particles can come from a variety of sources, including dust, pollen, smoke, and vehicle exhaust. PM_{10} is a common air pollutant that can have negative health effects, particularly for people with respiratory issues such as asthma. Governments and organizations often monitor PM_{10} levels in the air as part of efforts to improve air quality and protect public health.

Particulate Matter with diameters of 10 micron or less-PM_{10} were high during the whole study period and exceeded the maximum permission value of 45 ($\mu g/m^3$) in almost all sites. The minimum value of 5 ($\mu g/m^3$) was measured at site Baghy Shar during the 3rd sampling period whereas the maximum value of135 ($\mu g/m^3$) recorded at Pishasazy Bashur during the same period of study. On the other hand, the mean value for all sites was

exceeded the maximum permission level of 45 (µg/m^3) during the 1st and 2nd sampling period.

There are many sources of PM10 pollution, both natural and human-made. Some common sources of PM_{10} pollution include: Dust and soil: Natural sources such as dust and soil can contribute to PM_{10} pollution, particularly in dry and windy areas. Vehicle exhaust: Cars, trucks, and other vehicles can produce PM_{10} pollution, particularly from diesel engines. Industrial emissions: Manufacturing and other industrial processes can release PM_{10} pollution, particularly from sources such as power plants and factories.

Long-term exposure to PM_{10} has been associated with a range of negative health effects, particularly for people with pre-existing respiratory and cardiovascular conditions. Some of the health effects of long-term exposure to PM_{10} include: Respiratory problems, Cardiovascular problems and Cancer.

Table 4. PM_{10} concentration (µg/m^3) recorded at three sampling date during the study period, with WHO-Ambient Air Quality standards (WHO, 2022).

Sites	PM_{10} (µg/m^3) 1st Sampling	PM_{10} (µg/m^3) 2nd Sampling	PM_{10} (µg/m^3) 3rd Sampling
Shaqamy Pzishkan	41	**57**	21
Barrewabaraiaty Parwada	**54**	36	28
Baghy Shar	**55**	41	5
Mzgawty Choly	**70**	45	28
Regay Ainkawa (30-60m)	45	32	28
Ragay Masif-Naxoshkhanay Komary	**61**	37	28
Setaqan-Mzgawti Said Gharib	**48**	41	39
Parky Shanadar	28	**59**	**99**
Regay Ainkawa (60-100m)	**81**	30	45
Ragay Masif-Shorsh Market	**93**	25	30
Setaqan-Naxoshkhanay Rzgary	41	36	39
Regay Makhmur	**52**	**52**	45
Regay Ainkawa (100-120m)	37	43	**46**
Ragay Masif-Kurdnaft	**55**	27	**70**
Regay Koya, Rasuly Taibat	**46**	27	41
Pishasazy Bashur	**73**	**73**	**135**
Mean	**55**	41.313	**45.438**
WHO-Air Quality Standards-AQS	45	45	45

4.5. Carbon Dioxide-CO_2: CO_2 stands for carbon dioxide, which is a colorless, odorless gas composed of one carbon atom and two oxygen atoms. CO_2 is a natural component of the Earth's atmosphere and is essential for life on Earth, as it is a key component of the process of photosynthesis that plants use to produce food.

However, human activities such as burning fossil fuels (coal, oil, and natural gas) and deforestation have significantly increased the amount of CO_2 in the atmosphere, leading to global warming and climate change. CO_2 is a greenhouse gas, which means that it traps heat in the Earth's atmosphere and contributes to the warming of the planet.

Carbone dioxide concentrations were higher than AQS (>1000ppm) during the whole period of this study. The minimum value of 854 (ppm) was recorded at Regay Masif-Kurdnaft during the first sapling period while the maximum value of 1358 (ppm) was recorded at Regay Masif-Naxoshkhanay Komary during the same period. Generally, sites located in crowded area (i.e. Baghy Shar, Mzgawty Choly, Mzgawty Said Gharib and Pishasazy Bashur) were above the maximum permission level of carbon dioxide during the whole study period. These results indicate polluted air in crowded area in Erbil and other cities in KRI and Iraq.

Carbone dioxide is emitted into the atmosphere from a variety of natural and human-made sources. Here are some of the main sources of CO_2: Burning fossil fuels: The burning of fossil fuels (such as coal, oil, and natural gas) for energy production, transportation, and industrial processes is one of the main sources of CO_2 emissions from human activities. Land-use changes: Deforestation and other land-use changes, such as converting forests and grasslands into agricultural land, release large amounts of CO_2 into the atmosphere. Industrial processes: Industrial processes, such as cement production and metal smelting, can also release significant amounts of CO_2 emissions. Agriculture: Agricultural activities, such as livestock production and fertilizer use, can release significant amounts of CO_2 and other greenhouse gases. Natural sources: Natural sources of CO_2 include volcanic eruptions, wildfires, and decomposition of organic matter. Transportation: Cars, trucks, airplanes, and other modes of transportation that run on fossil

fuels are a significant source of CO_2 emissions. Electricity generation: Electricity generation from fossil fuel-fired power plants is a significant source of CO_2 emissions.

Reducing CO_2 emissions from these sources is critical to addressing climate change and protecting the planet. This can be done through a combination of technological solutions, policy changes, and individual actions to reduce energy consumption and adopt more sustainable practices.

Table 5. Carbon Dioxide CO_2 concentration (ppm) recorded at three sampling date during the study period, with WHO-Ambient Air Quality standards (WHO, 2022).

Sites	CO_2 (ppm) 1st Sampling	CO_2 (ppm) 2nd Sampling	CO_2 (ppm) 3rd Sampling
Shaqamy Pzishkan	931	988	915
Barrewabaraiaty Parwada	927	939	977
Baghy Shar	**1011**	971	907
Mzgawty Choly	**1046**	**1015**	892
Regay Ainkawa (30-60m)	**1019**	**1014**	931
Ragay Masif-Naxoshkhanay Komary	**1358**	931	924
Setaqan-Mzgawti Said Gharib	**1068**	**1188**	**1053**
Parky Shanadar	979	988	875
Regay Ainkawa (60-100m)	**1065**	989	951
Ragay Masif-Shorsh Market	995	963	**1140**
Setaqan-Naxoshkhanay Rzgary	933	**1284**	924
Regay Makhmur	875	875	**1123**
Regay Ainkawa (100-120m)	971	**1006**	991
Ragay Masif-Kurdnaft	854	924	**1173**
Regay Koya, Rasuly Taibat	907	972	**1020**
Pishasazy Bashur	875	**1170**	**1115**
Mean	988.375	**1013.563**	994.438
WHO-Air Quality Standards-AQS	1000	1000	1000

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions:

During the period of the study, the following conclusions were noted:

1. Formaldehyde-HCOH levels were higher than WHO-Ambient Air Quality standards (AAQS) and exceeded 0.050 mg/m^3.

2. Total Volatile Organic Compounds- TVOC were lower than the maximum permission level of 5 (mg/m^3) at all sites during the whole study period.

3. Particulate Matter with diameters of 2.5 micrometers or less-$PM_{2.5}$ and particulate Matter with diameters of 10 micrometers or less-PM_{10} were high during the whole study period and exceeded the maximum permission value of 15 ($\mu g/m^3$) and 45 ($\mu g/m^3$) respectively in almost all sites.

4. Carbone dioxide-CO_2 concentrations were higher than AQS (>1000ppm) during the whole period of this study.

5. Crowded area in Erbil city (inside 30m and 60m circles) characterized by high air pollution.

5.2. Recommendations:

1. Reduce vehicle use: Use public transportation, bike, or walk instead of driving alone.
2. Reduce waste: Recycle and compost to reduce the amount of waste sent to landfills, which produce methane gas.
3. Use natural cleaners: Use non-toxic, biodegradable cleaning products instead of harsh chemicals.
4. Plant trees: Trees absorb carbon dioxide and other pollutants from the air.
5. Support clean energy: Invest in renewable energy sources like solar and wind power.
6. Raise awareness: Educate others about the importance of reducing air pollution and encourage them to take action.

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