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IMPACTS OF MUNICIPAL SOLID WASTE ON AIR QUALITY IN DUHOK CITY, KURDISTAN REGION OF IRAQ

BAHZAD M. TAHER KHALED

University of Duhok, College of Agricultural Engineering Sciences, Department of Horticulture.
Email: Bahzad.khaled@uod.ac

Abstract

Recently and because of urbanization, industrialization and rapid population growth, the global per capita generation of municipal solid waste (MSW) is projected to reach approximately 2.2 billion tonnes by the year 2025. In developing countries like Iraq including Kurdistan region, in excess of 80% of municipal solid waste (MSW), usually MSW composed of plastics, food waste, glass, paper, metals, and textiles, materials., garden residues and other materials in different percentage are directly dumped into the landfill without separation and recycling process, that's leads to the generation of landfill gas (LFG), Methane (CH_4) and carbon dioxide (CO_2) emissions from the Kuashe landfill in Duhok were quantified by assessing the outcomes of physical, chemical, and microbial processes occurring within the waste by using the portable gas detector (JD-3002) during two consecutive year 2021and 2022. Results indicate that's the per capita generation of MSW is 0.87 kg/person/day and the highest percentage of MSW in Duhok is food residual 47%, therefore Kuashe landfill is became an active source of greenhouse gases specially CH_4 and CO_2 in Duhok city, which is positively accelerating climate change in the region. A seasonal variation in CH_4 and CO_2 emission from the landfill were observed during both year of the study, which is mainly because of the variation in meteorological conditions like temperature, precipitations, wind speed and variation in soil conditions from one season to another.

Keywords: MSW, Air Quality, CO_2, CH_4, Climate Change.

INTRODUCTION

In 21st century and because of urbanization, industrialization and rapid population growth municipal solid waste (MSW) generation per capita, and for whole community according to Hoornweg and Bhada-Tata (2012), it is anticipated that global municipal solid waste (MSW) will reach approximately 2.2 billion tonnes by 2025. Typically, MSW includes items like plastics, food waste, glass, paper, metals, textiles, garden residues, and other materials. Nevertheless, there are variations in the composition of MSW observed worldwide. Developing countries tend to have a higher proportion of organic waste in their MSW, whereas developed countries exhibit greater diversity with a relatively larger share of paper and plastics in their municipal solid waste profiles. (Keotiamchanh S, 2018).

In Iraq, including Kurdistan Region, and Erbil city as a case study household waste is mainly consisting of organic fraction such as food scrape which is constitutes about 76% of the municipal solid waste (Shekha, Y.A., 2011). The substantial portion of organic waste within municipal solid waste is regarded as a factor that contributes positively to climate change. This is because it can lead to increased emissions of greenhouse gases (GHGs), such as CO_2 and CH_4, especially when it undergoes unregulated decomposition. This uncontrolled decomposition has the potential to contaminate soil, water, and the atmosphere (Sisto *et al*., 2017).

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Throughout the biodegradation process of municipal solid waste in landfill sites, CO_2 and CH_4 are typically generated, usually in anaerobic conditions. The proportions of these gases, about 45% CO_2 and 50% CH_4, can vary depending on factors like the quantity of organic material in the waste, landfill cover, moisture levels, and temperature, as noted by (Czepiel et al. 1996). The complex decomposition of organic waste involves multiple stages where aerobic bacteria initially break down the waste, eventually transitioning to anaerobic bacteria. CH_4 is produced in the later stages, arising from the decarboxylation of acetic acid or the reduction of CO_2. It's important to note that CO_2 is generated throughout all stages of waste degradation, as explained by (Themelis and Ulloa, 2007).

Carbon dioxide (CO_2) and methane (CH_4) are considered the most significant anthropogenic greenhouse gases (GHGs) due to their high global warming potential (GWP) over a 100-year period, as highlighted by (Myhre et al., 2013). While there is a reasonably good understanding of CO_2 and CH_4 emissions globally, uncertainties persist at the local and regional levels, particularly when it comes to emissions from specific sources, as discussed by (Dlugokencky et al., 2011). The Climate Change Act of 2008 has legally obligated developed and industrialized nations to reduce carbon emissions from GHGs by 80% by 2050 compared to the 1990 baseline. Consequently, a comprehensive understanding of the sources and emission magnitudes of CO_2 and CH_4 is crucial on local, regional, and global scales, as emphasized by (Brown et al.,2016).

The existing situation of solid waste management in Duhok municipality is struggling to keep up with the growing demand, and because of the lack of modern technology for recycling of MSW contents, non-professional human resources and equipment for collecting, transporting and managing solid waste, in addition to unsorted waste at household level make the situation worst and more than 80% of MSW is directly dumped to the landfill, open dumping not only contributes to aesthetic degradation but also exacerbates environmental contamination. Therefore, the aim of the study is to explore the composition of Duhok MSW contents and to estimate the contribution of different gases like CO_2 and CH_4 emitted from the landfill which cause air pollution in Duhok city and around.

MATERIALS AND METHODS

Data collection for the first experiment: was performed one time during February, March and April of 2021, where 130 house hold were selected randomly from north to south and east to west in order to cover different part of Duhok city, where in the study areas, individuals from diverse social, cultural, economic, religious backgrounds, and more could be encountered. The residents were inquired whether the solid waste produced within a 24-hour timeframe was collected or not. Samples were collected every day in the morning during three months of the field work, each sample was labeled with household basic information and taken to a specific place in order to separate the different components of each sample, weighted by digital balance and recorded separately according to (Bernache- Perez et. al., 2001).

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Data collection for the second experiment: was conducted over the course of two consecutive years, specifically in 2021 and 2022, at the Kuashe landfill situated in Sumail district, located approximately 10 kilometers northwest of Duhok. The objective was to monitor the concentrations of gaseous pollutants, specifically carbon dioxide (CO_2) and methane (CH_4), which are the primary gases emitted from the landfill into the surrounding air. This was achieved using a portable multi-gas detector (JD-3002) air quality meter, as well as temperature and humidity monitoring equipment (manufactured in China), along with a multi-gas detector (SA-201) from Beijing Shi'an Tech Instrument, China.

Fieldwork was conducted during midday hours for both years, 2021 and 2022, and measurements were taken once per week at random intervals to ensure that the data collected closely represented real-world conditions. Additionally, meteorological parameters, such as soil temperature and relative humidity, were measured simultaneously during the sampling process using specialized instruments for each parameter.

Statistical analysis: The study's data underwent statistical analysis using SAS 9.4 software developed by SAS Institute, Inc. in Cary, North Carolina. The analysis involved conducting one-way ANOVA, as well as correlation and regression analyses, following the methodology outlined by (Duncan, 1955).

RESULTS AND DISCUSSION

The data analysis of **figure 1** show the composition of solid waste in Duhok city, where the majority were occupied by food garbage 47%, followed by plastic and nylon materials 29%, glasses 7%, paper 6% etc. Understanding the composition of solid waste is essential for designing effective waste management strategies, these information's are crucial for identify opportunities for recycling, recovery, and diversion of waste away from landfill, Simultaneously, the aforementioned results were derived from a survey that involved chosen families, and these families were considered to be representative of the city in terms of its cultural, religious, economic, and social characteristics, as noted by Al-Rawi and Al-Tayyar in 2012.

This was done to provide an approximate estimation of the per capita generation of solid waste in Duhok city based on the study's sample size, where (family numbers = 130, total family members = 910, solid waste quantities 800 kg) consequently the per capita generation is becoming 0.87 kg/person/day, and this is very reasonable and agree with results of many researchers conducted in different cities of Iraq (Al-Wattar, 2006; Tahir, T.A., 2017; Abdulredha, M., et al, 2020). Economic and population growth in Kurdistan Region including Duhok city has yielded numerous advantages, including elevating quality of life and enhancing overall lifestyles. However, this progress has also led more per capita generation of solid waste, exhaustion of natural resources and the deterioration of ecosystem (AL-Ghabban, M.M., et al, 2018).

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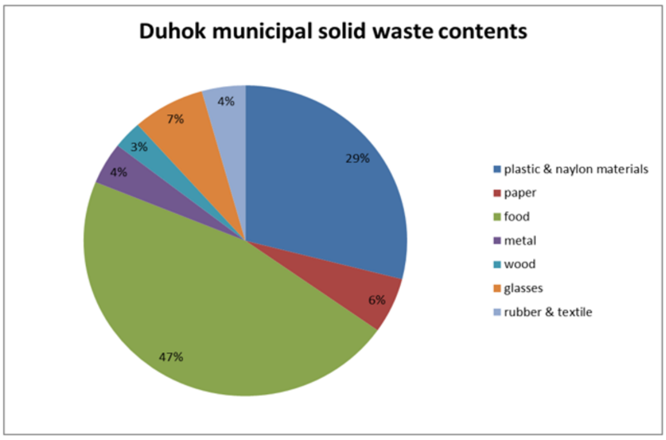

Figure 1: Municipal solid waste (MSW) contents after separating, as an average of 130 samples

Figure 2 and 3 demonstrates the seasonal variation in carbon dioxide CO_2 and methane CH_4 emission from the Kuashe landfill, were highest concentration of CO_2 recorded during summer season (July, August and September) of both years of the study 2021-2022, while highest concentration of CH_4 were recorded during Spring season (March, April and May) during both years of the study 2021-2022. Landfilling which is involves compacting municipal solid waste (MSW) within a landfill, resulting in the production of landfill gas (LFG) through physical, chemical, and microbial processes within the waste. The microbial anaerobic breakdown of organic materials within the waste generates a diverse blend of gases (Das et al., 2016).

The primary constituents of LFG are typically methane (CH_4) at around 45% to 60%, carbon dioxide (CO_2) at approximately 40% to 60%, and small amounts of various other compounds such as N_2O. The rapid increase in the atmospheric concentrations of carbon dioxide (CO_2) and methane (CH4) is a significant human-induced factor contributing to greenhouse gas (GHG) emissions, and it plays a major role in the current and anticipated climate change worldwide, as noted by the (IPCC., 2013 and Mønster et al.,2019). Among these gases, methane (CH_4) and carbon dioxide (CO_2) are the primary culprits, with methane's global warming potential (GWP) being 20 to 28 times higher than that of carbon dioxide over a 100-year period, as reported by (Olivier et al.,2017).

The composition of biodegradable waste, moisture levels, and the way waste is covered, either temporarily or finally, in landfills are crucial factors that influence the release of GHGs into the atmosphere, as pointed out by (Gollapalli and Kota 2018). Furthermore, variations in CH_4 and CO_2 emissions are linked to various factors such as the thickness of the landfill cover, local meteorological conditions (including factors like wind speed, atmospheric pressure, temperature, precipitation, and solar radiation), and the conditions of the soil/cover layer (including aspects like cracks, permeability, porosity, moisture content, organic content, and CH_4 oxidation capacity), all of which impact the emission of landfill gas from the landfill surface, according to research by (Fjelsted et al., 2019). A reduction in the thickness of the cover leads to heightened diffusion and convection, resulting in an increase in surface

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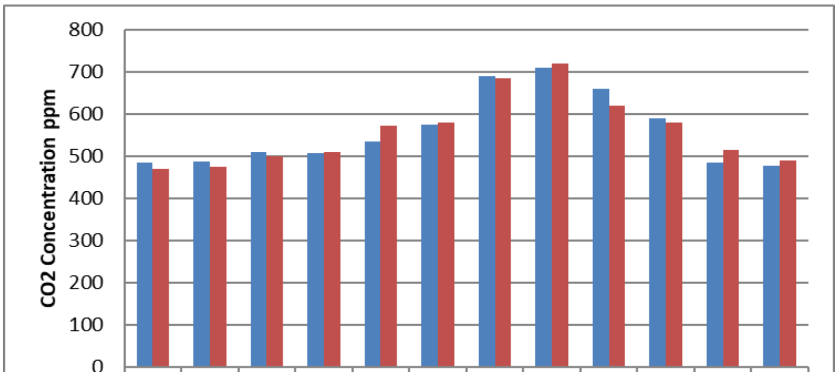
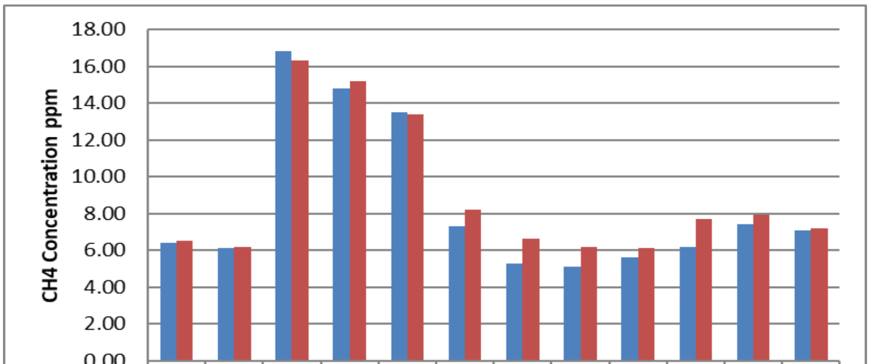
emissions. Higher wind speeds facilitate the movement of landfill gas (LFG) to the surface through diffusion. Increased solar radiation elevates internal pressure, aiding the upward movement of LFG through convection. Greater rainfall decreases the porosity and permeability of the cover, consequently lowering surface emissions (Aghdam et al., 2019). Therefore, the main difficulties encountered in quantifying landfill gas (LFG) emissions involve the fluctuations in flux rates over time and space due to the interaction of several factors, as well as constraints associated with quantitative methods for conducting field measurements (Mønster et al.,2019).



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2021	485	488	510	508	535	575	690	710	660	590	486	478
2022	470	475	500	510	573	580	685	720	620	580	515	490

Figure 2: Monthly average of carbon dioxide (CO2) concentrations ppm of two years 2021, 2022in Kuashe landfill



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2021	6.40	6.10	16.8	14.8	13.5	7.30	5.30	5.10	5.60	6.20	7.40	7.10
2022	6.50	6.15	16.3	15.2	13.4	8.20	6.60	6.20	6.10	7.70	7.90	7.20

Figure 3: Monthly average of methane (CH4) concentrations ppm of two years 2021, 2022 in Kuashe landfill

In **figure 4**, and in order to determine the relationship between CO_2 emission from the landfill and soil temperature a scatter diagram was used, which indicates a positive correlation between CO_2 concentration in the atmosphere and soil temperature with R^2=0.93. Throughout both

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years of the study, it was evident that CO_2 concentrations exhibited noticeable variations in response to temperature fluctuations.

Figure 4 and 6 depict the intricate relationship between temperature and the emissions of CO_2 and CH_4 from landfills. This connection is highly intricate and can be influenced by numerous factors, including the composition of the waste, the design of the landfill, and the practices used for its management. Furthermore, the specific effects of temperature on emissions may differ based on regional climate patterns and the specific conditions at a given landfill.

In a general sense, higher temperatures can expedite the decomposition process and boost the activity of microorganisms responsible for breaking down organic waste within landfills. This heightened microbial activity leads to a more rapid breakdown of organic materials, resulting in increased emissions of both CO_2 and CH_4. The elevated temperature also creates a more favorable environment for the growth and metabolic processes of microorganisms, leading to accelerated rates of waste degradation and the subsequent production of gases (Pehme, K.M. et al., 2020, Hafner, S. D., & Stucki, S., 2019).

On the other hand, higher temperature could enhance methane production in the landfill driven by anaerobic microbial process, also higher temperature could reduce methane oxidation, and the efficiency of methane oxidation by soil bacteria can decrease, allowing more methane to escape into the atmosphere rather than being converted to CO_2 when favorable conditions for CO_2 production are prevailing like moisture deficiency in the landfill (Themelis, N.J. and Ulloa, P.A., 2007., Reddy, K.R.,et al, 2018).

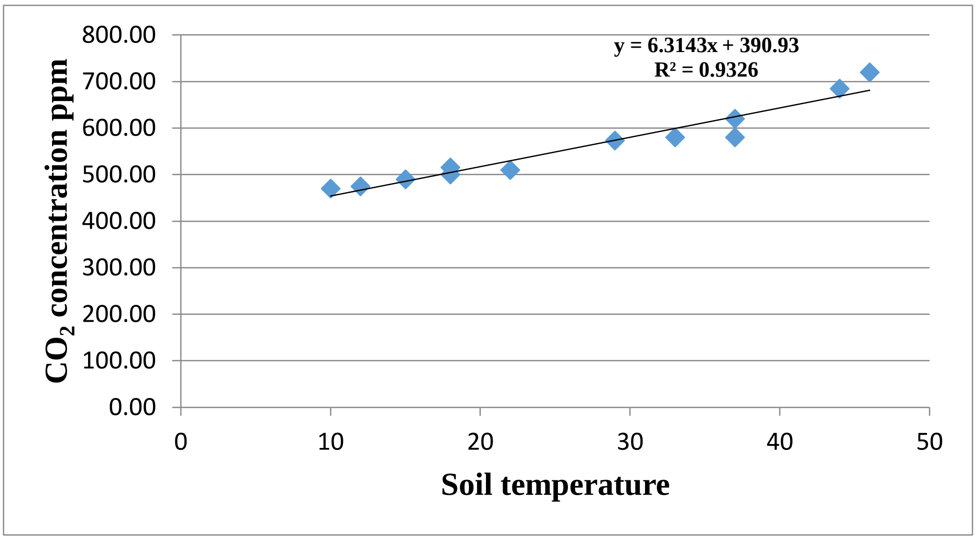

Figure 4: Correlation between carbon dioxide (CO2) concentrations ppm and monthly average soil temperature

In **figure 5**, and in order to determine the relationship between CO_2 emission from the landfill and soil moisture content a scatter diagram was used, which indicates a negative correlation between CO_2 concentration in the atmosphere and soil moisture content with R^2=0.60.

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Throughout both years of the study, it was evident that CO_2 concentrations exhibited noticeable variations in response to soil moisture content change.

In the context of landfills, carbon dioxide (CO_2) emissions primarily result from the degradation of organic materials found in the waste stream, such as food waste and yard waste. These organic materials undergo both aerobic and anaerobic decomposition processes, which release CO_2 into the atmosphere as a byproduct. It's important to emphasize that the moisture content of solid waste plays a critical role in the emissions of gases from landfills (Cossu, R., & Lai, T., 2013)

Having an appropriate level of moisture is essential to support microbial activity and the decomposition processes that take place in landfills. If there is insufficient moisture, it can hinder the breakdown of organic waste and the production of methane (CH_4). Conversely, if there is an excess of moisture, it can create anaerobic conditions, which promote the generation of methane but inhibit the oxidation of methane into CO_2. Therefore, maintaining the right balance of moisture is crucial in managing landfill gas emissions effectively (Reinhart, D., & Townsend, T., 2018).

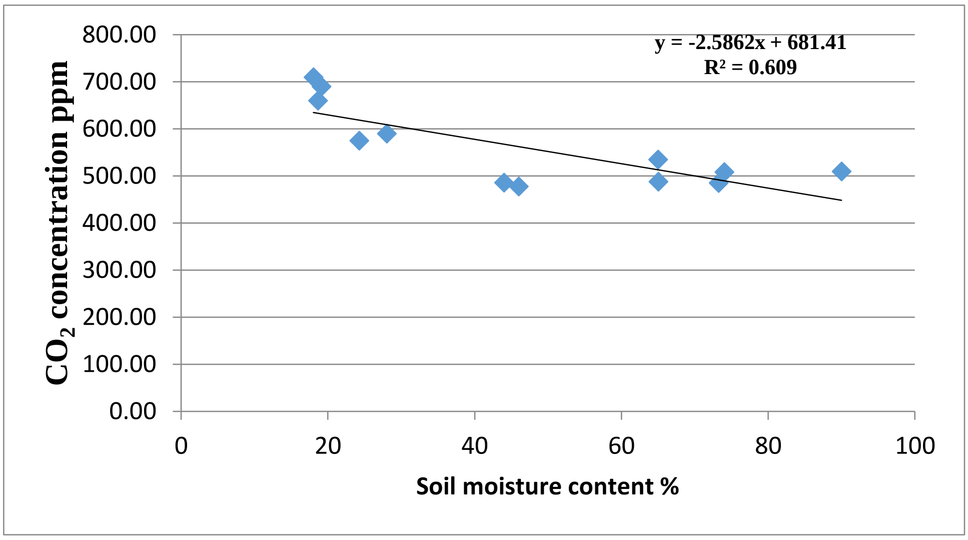

Figure 5: Correlation between carbon dioxide (CO2) concentrations ppm and monthly average soil moisture content %

In **figure 6**, and in order to determine the relationship between CH_4 emission from the landfill and soil temperature a scatter diagram was used, which indicates a weak correlation between CH_4 concentration in the atmosphere and soil temperature with R^2=0.10. Throughout both years of the study, it was evident that CH_4 concentrations exhibited small variations in response to temperature fluctuations.

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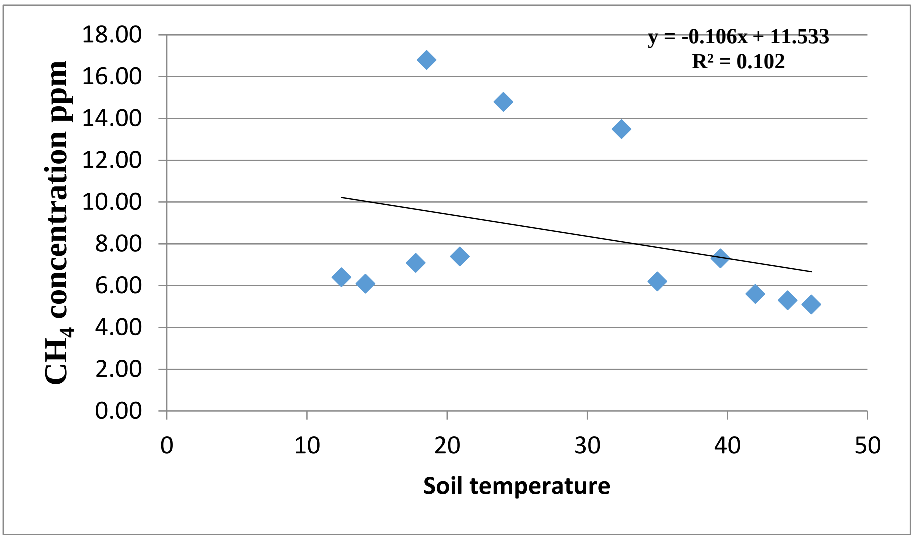

Figure 6: Correlation between methane (CH4) concentrations ppm and monthly average soil temperature

In **figure 7**, and in order to determine the relationship between CH_4 emission from the landfill and soil moisture content, a scatter diagram was used, which indicates a positive correlation between CH_4 concentration in the atmosphere and soil moisture content with R^2=0.56. Throughout both years of the study, it was evident that CH_4 concentrations exhibited noticeable variations in response to soil moisture content change.

The production of CH_4 in the landfill showed an exponential rise as the soil moisture content increased. This outcome was expected because higher soil moisture content leads to the saturation of more pores within the solid waste in the soil. This, in turn, facilitates the creation of anaerobic zones that support anaerobic metabolism and the production of methane through the methanogenesis process, as discussed in studies by (Agnew and Leonard, 2003 and Richard et al., 2002).

Across Europe, the climate varies considerably, leading to differences in methane generation from household waste between countries like Finland and Italy. The methane formation potential is generally determined by two main factors: the total amount of organic materials present and landfill design and operation. Additionally, climate conditions, especially temperature and precipitation, play a crucial role. These climate factors affect the rate at which waste decomposes and the total amount of methane produced per ton of waste, as outlined by (Oonk, 2010).

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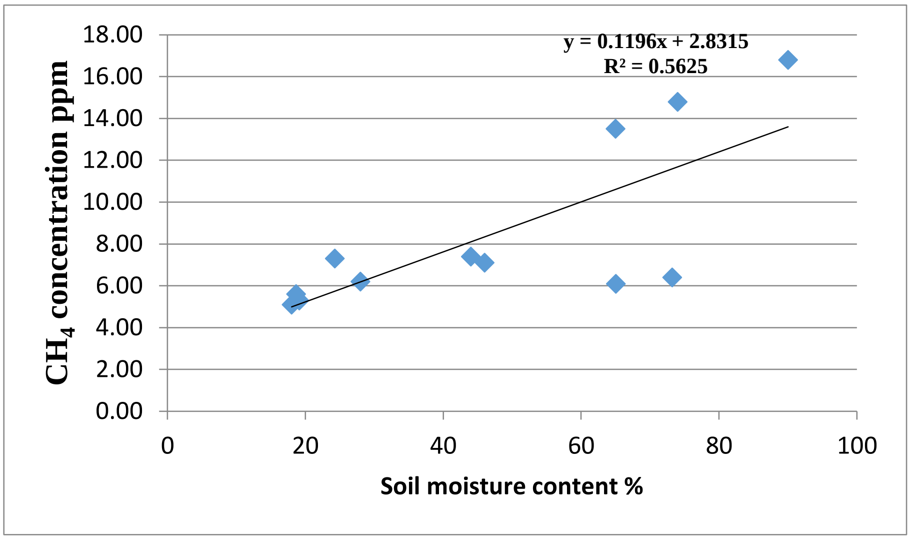

Figure 7: Correlation between methane (CH4) concentrations ppm and monthly average soil moisture content %

CONCLUSION

Landfill gases (LFG) emission from Kuashe landfill in Duhok city, primarily methane (CH4) and carbon dioxide (CO2), have a significant impact on air quality of Duhok city and surrounding area. These gases are considered as major contributors to greenhouse gas emissions which accelerating climate change phenomenon locally, regionally and globally. The composition of municipal solid waste (MSW), meteorological conditions, landfill design and management process and other factors affecting on the variation of LFG emission. Overall, addressing the impact of landfill gases on air quality is essential for both mitigating climate change and protecting the health and well-being of human, plants and animal's communities living near the landfills.

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