Iraqi Journal of Agricultural Sciences –2026:57(1):295-306
P-ISSN: 0075- 0530/ E-ISSN: 2410-0862
DOI: https://doi.org/10.36103/335eqs49

MITIGATING METHANE EMISSIONS FROM ERBIL WASTE DUMPING SITE: A GIS –BASED APPROACH TO DETECTION AND CONVERSION INTO A GREEN LANDSCAPE

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ABSTRACT

This work uses Geographic Information System (GIS) technology, particularly ArcMap, to address the serious environmental issue of methane (CH4) leaks from the Kane Qrzhala waste dumping site Sub district in Erbil City, at latitudes 36°10'23"- 36°52'25" N and longitudes 43°35'32"- 44°23'43" E. The aim of this research is to identify and analyze methane concentrations in the neighborhood of the dumping site, offering significant data for environmental monitoring and mitigation techniques. "This study employs an integrated approach combining spatial data and satellite imagery. Methane emission levels were extracted from two publicly accessible platforms: earth.jpl.nasa.gov and dataspace.copernicus.eu.", and ground measurements to map and quantify methane emissions. The findings contribute to the understanding of the spatial distribution of methane emissions, enabling targeted interventions to reduce environmental harm. Furthermore, the research investigates sustainable alternatives to reducing methane emissions by identifying that the garbage dumping site be converted into a green area and, eventually, a forest. The methane plume spanned 26.768 km² with a concentration of 3471 ppm—over twice the safety limit—posing a serious environmental and health risk and demanding urgent action to control emissions. Beyond methane reduction, the benefits of transforming the dumping site into a green space include improved air quality, increased biodiversity, and the construction of a community recreational area. Finally, this study not only extends to our awareness of the release of methane from waste disposal sites, however it also advocates for the conversion of such sites into environmentally beneficial landscapes.

Key words: Methane gas, Erbil waste dumping site, Green area, environmental

Received: 14/4/2025, Accepted: 2/7/2025, Published: 26/1/2026

INTRODUCTION

Methane emissions from waste dumping sites contribute significantly to environmental degradation and climate change. This scientific research aims to address this critical issue by focusing on the waste dumping site in Erbil, Kurdistan Region-Iraq. The study incorporates a GIS-based approach, leveraging Geographic Information Systems to assess and mitigate methane emissions. Methane, being one of the major greenhouse gases (GHGs), has been estimated to have twenty-eight times the global warming potential (GWP) of carbon dioxide over a 100-year time horizon in the IPCC Fifth Assessment Report; its GWP over a 20-year course is approximately 84 times that of carbon dioxide (Zhao, et al. 2019). The recently observed rise in atmospheric methane is mostly allocated to human-caused processes such as grazing animals, rice fields, garbage dumps, combustion of biomass, fossil fuels mining operations, and natural gas leakage

Iraqi Journal of Agricultural Sciences –2026:57(1):1-18
P-ISSN: 0075- 0530/ E-ISSN: 2410-0862
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during transmission. The impact of human methane emissions from organic material are caused primarily by bacterial anaerobic decomposition, although they can also be caused by uncompleted combustion. Multiple modifications have been made to the estimated collapses and producers in order to reconcile them with observed air concentrations (Peer, et al. 1993). Landfill gas is produced when organic waste in landfills decomposes anaerobically. The major components of LFG are methane (CH_4: 55-60% by volume) and carbon dioxide (CO_2: 40-45% by volume), the synthesis of which goes through three initial sequential phases followed by a steady CH_4 and CO_2 production phase LFG will continue to form until the majority of the organic content in the waste is decomposed, which might take many years. Gas from landfills that is not collected or degraded microbial in the landfill cover is released into the atmosphere. Meteorological conditions (barometric the pressure, rainfall, temperature, and wind direction), soil/cover circumstances (fractures, cracks, flexibility, diffusivity, permeability, water content, organic matter, CH_4 oxidation capability), as well as garbage or landfill conditions (gas production rate, internal obstacles, propane vents, lateral migration space) are the factors influencing the methods of transportation of LFG that cause CH_4 relocation and emission. Spatial and temporal fluctuations in soil physical and chemical variables that influence soil gas transport and microbial activity (composition, depth, moisture, temperature, aeration status) are particularly important (Mønster, et al. 2019). Over the last decade, satellite data of atmospheric composition has grown as a viable resource for estimating gas emissions. We examine current, near future, and potential satellite measurements of atmospheric methane and estimate their use for determining emissions at regional, national, and individual point source scales (Jacob, et al. 2016). Plants may additionally improve the power of surface soils to oxidize CH_4 by transferring oxygen into the root zone via stems (Bian, et al. 2019). Furthermore, vegetation impacts the chemical and physical features of soils, such as density, water content, and porosity, which affects the capacity of CH_4 reduction. Trees in natural tropical and temperate ecosystems provide a route for CH_4 emissions from subsurface sources to the atmosphere through absorption or transpiration. Furthermore, in marsh and highland habitats, stem CH_4 fluxes differ dramatically among tree species. Trees provide a conduit for belowground CH_4 to circumvent oxidation in a garbage dump area; however, plant roots flow differently (Fraser-McDonald, et al. 2022). The current research extends this GIS-based approach to the specific context of methane emissions from the Erbil waste dumping site. Additionally, it explores innovative strategies for converting methane emissions into a green landscape, offering a sustainable solution to mitigate environmental impacts.

MATERIAL AND METHODS

The investigation area is located north toward the Kane Qrzhala Sub district in Erbil City, near to the Erbil-Mosul mainline road in Iraq, at latitudes (36°10'23"- 36°52'25" N) and longitudes (43°35'32"- 44°23'43" E). The garbage dumps, which began operations in 2001, encompasses 37 acres and is mostly occupied. This statistic is based on data gathered from ELS staff members, which receives almost 2000 tons of municipal solid waste daily. Waste is dumped without being separated and is buried by layers of soil. The location, which is now a garbage and septic tank discharge area, exemplifies the rising environmental repercussions. According to Yachiyo Engineering Company's assessment on trash composition in Erbil province, food waste accounts for 31% of the total, with all

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plastic products accounting for 27.7%. Erbil lacks recycling facilities and relies on Kane Qirzhala for waste collection and disposal hub. Managing 2000 tons per day across 37 hectares. Only 25% remains for future usage after 75% consumption. According to Japan International Cooperation Agency assessments, only 7 of the 23 needed disposal site points exist, with no preparations for a new site. Kane Qirzhala, 15 kilometers from Erbil's downtown, has amassed a 35-meter landfill height over the course of 22 years, amounting to 328,500 tons each year. An on-site visit is required to understand the coming ecological problem, which has been aggravated by protracted gas emissions and a recent landfill fire, which has resulted in unpleasant smoke and a widespread odor (Aziz, and Mustafa, 2019).

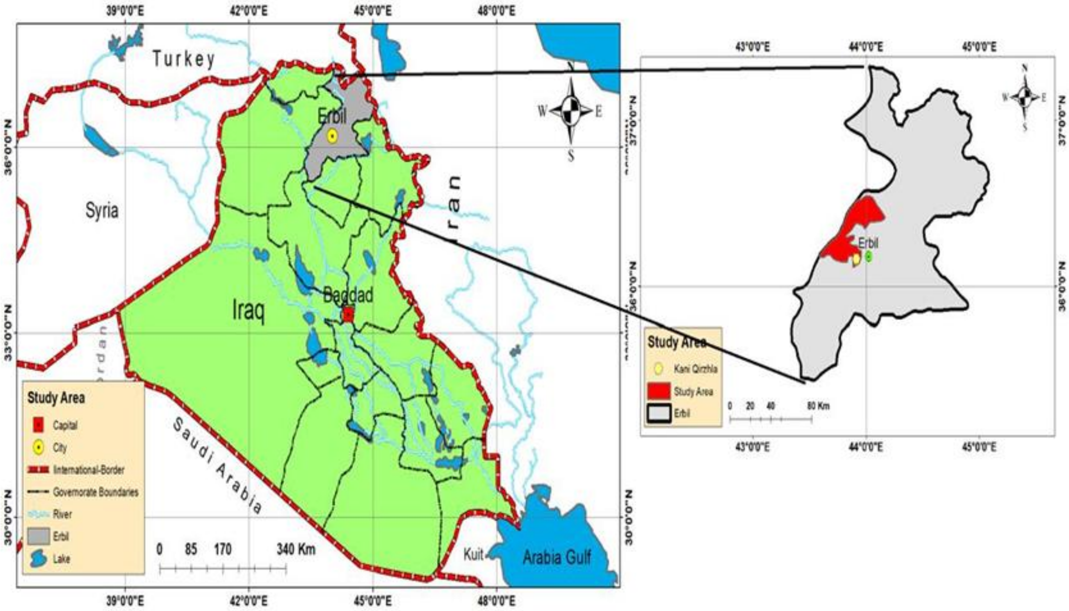

Figure 1. Erbil Kani Qrzhala Area

The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories are referred to in the IPCC 1996 Guidelines. The United Nations Framework Convention on Climate Change (IPCC) produced these guidelines to provide a consistent method for countries to estimate and report their greenhouse gas emissions.The recommendations provide detailed approaches and procedures for assessing emissions from diverse sectors such as energy, industrial operations, agriculture, and trash. They provide a framework for calculating greenhouse gas emissions such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O).The Reference Manual (Volume 3) is an important component, serving as a compilation of knowledge on methodologies for estimating emissions for a wide range of greenhouse gases. These guidelines seek to improve the consistency and comparability of greenhouse gas inventories around the world, assisting countries in meeting their reporting commitments under international climate agreements.

THE DEFAULTS METHOD

The mass equilibrium method, referred to as the default IPCC (1996) methodology, is a prevalent technique for predicting methane emissions from landfills, particularly in scenarios with little data. Utilizing empirical constants such as the methane correction factor and degradable organic carbon (DOC), it presumes that all methane is released in the year of trash disposal. This approach, although useful for broad estimations, may

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exaggerate emissions due to its oversimplified assumptions.

CH_4 emission (Gg yr^{-1}) $= (MSW_T \times MSW_F) \times MCF \times DOC \times DOC_F \times F \times (^{16}/_{12} - R) \times (1 - OX)$ …… (1)

MSW = Total municipal waste solid (Gg yr^{-1})

MSW_T= Can be calculated from population in thousands person x annual MSW Generation (Gg 10^{-3} $pesons\ yr^{-1}$)

MSW_F = Fraction of MSW garbage at the disposal site, the percentage 0f 70% is based on field investigation studies, the remaining 30 % is assumed to be lost due to recycling, waste burning at sources and waste not reaching to site due to improper solid waste management.

MCF= Factor of adjustment for methane (fraction). The fraction is determined by the type of disposal and the depth available at landfills, The IPCC publication specified a value of 0.4 for open dumps of 5m depth, which was used for computation.

DOC = Organic carbon that degrades (fraction), DOC content is critical in calculating methane production. It is determined by the makeup of the garbage and differs from city to city. DOC values are calculated as:

0.4A + 0.17B + 0.15C + 0.3D … (2)

Where:

A=paper + trash B=leaves + grass + straw; C stands for fruits and vegetables; D=wood

DOC_F=Fraction DOC was dissipated. A portion of the DOC is transformed to LFG. The calculations are based on a theoretical model that vary only with temperature in a landfill's anaerobic zone. The model is defined as 0.014T+0.28, where T is the temperature in Celsius (Tabasaran, IPCC paper 1996). It is expected that the temperature in the landfill's anaerobic zone remains constant at 35 degrees Celsius. As a result, the value is computed as 0.77 and adopted.

F = Methane fraction in LFG (default is 0.5). The methane proportion in LFG is considered to be 0.5 as a default value and is used.

R = Methane recovered(Gg yr^{-1}). Because LFG recovery is not practiced in the Erbil/Kurdistan region, the value is 0.

OX = The oxidation factor (the default value is 0). It compensates for methane oxidation in the higher layer of waste matter when oxygen is present, Oxidation may minimize the amount of methane produced and subsequently expelled, and however, no universally acknowledged factor exists and can be presumed to be zero.

Using online sharing to quantify satellite-measuring gas emissions : Satellites having sophisticated detection technologies are transforming the observation of gas emissions, especially methane. MARS (Methane Remote Sensing), a cutting-edge worldwide methane detection system based on satellites, is at the top of this effort. Employing high-tech satellite technology, the system intends to improve the global accuracy of methane emission detection. Satellites use a variety of technology, including speed cameras in orbit, to measure methane concentrations. Satellites detect methane quantities by studying the reflection of sunlight off the Earth's surface, bringing in an age of emissions monitoring and transparency. The growing ecosystem of methane-detecting satellites gives important information about the sources and quantity of methane emissions. These satellites detect massive methane emissions from a variety of sources, including coal mines, waste dumps, and refinery locations around the world. Although unique data on the quantity of gas emissions that are shared online might not be readily available, the mentioned satellites and detection mechanisms provide greatly to an in-depth knowledge of global methane emissions, facilitating informed decision-making and environmental management; in this research,

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the amount of methane gas was selected from the two websites (earth.jpl.nasa.gov) and (dataspace.copernicus.eu).

RESULT AND DISCSSION

Due to an increase in greenhouse gas concentrations, particularly methane, in Erbil, our investigation attempts to understand the underlying causes and implications. The goal is to provide an initial basis for discovering effective solutions to the boosted methane levels in the area. We reached appropriate results by combining mathematical and satellite methodologies.

DEFULT METHOD

Considering the default approach defined in the Revised IPCC (1996) recommendations for predicting methane emissions from solid waste disposal sites, it uses statistics from the World Population Review to forecast population growth from 2020 to 2033. Simultaneously, determining the daily solid waste per generation rate (GR) in Erbil, as suggested by Aziz et al. (2022), Using Equation 3,

$$GR = \frac{Weight\ of\ collected\ solid\ (Kg)}{Population \times Duration\ (day)} \times 100\% \quad (3)$$

The amount of solid waste produced daily by the chosen inhabitants is calculated and converted to gigagrams (Gg) annually, as shown in Table 1.

Table 1. Estimation of Solid Waste from MSW landfills using the default method on national basis for the 2020 till 2033

Year	Population	Generation rate Gr Kg/capita/day	Solid waste (kg/day)	Solid waste (ton/day)	Solid waste (Gg/year)
2020	846,000	2.3	1,945,800	1,946	710
2021	861,158	2.3	1,980,663	1,981	723
2022	877,888	2.3	2,019,142	2,019	737
2023	896,716	2.3	2,062,447	2,062	753
2024	917,639	2.3	2,110,570	2,111	770
2025	940,560	2.3	2,163,288	2,163	790
2026	965,261	2.3	2,220,100	2,220	810
2027	991,505	2.3	2,280,462	2,280	832
2028	1,019,038	2.3	2,343,787	2,344	855
2029	1,047,690	2.3	2,409,687	2,410	880
2030	1,077,270	2.3	2,477,721	2,478	904
2031	1,107,667	2.3	2,547,634	2,548	930
2032	1,138,786	2.3	2,619,208	2,619	956
2033	1,170,656	2.3	2,692,509	2,693	983

To calculate the Dissolved Organic Carbon (DOC) in the Default formula, the composition of waste components in Erbil must be investigated. To do this, we used information from a survey conducted by the Japanese company (Yachiyo Engineering Company in 2022) and research performed by (Aziz, et al. 2023). Table 2 displays the detailed results of these research.

Table 2. Solid Waste Composition in Erbil

Type	Quantity (%)
Wood	2.18
Plastic (all type)	17.14
Clothes	2.36
Plastic bottle , water bottle	7.02
Plastic , nylon	1.21
Paper	1.51
Organic substances	7.1
Iron	2.67
Inorganic substances	3.76
Grasses and Bushes	4.05
Glass	2.66
Food Waste	31.41
Diaper	6.4
Carton	9.69
aluminum	0.84

Source: JICA

Iraqi Journal of Agricultural Sciences –2026:57(1):1-18
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Methane emissions were calculated using Equation1 & 2, frequently referred to as the default technique. Methane emissions from 2020 to 2033 were calculated by plugging all necessary variables into the equation, and the results are shown in Table (3).

Table 3. Estimation of methane emission from MSW landfills using the default method on national basis for the 2020 till 2033

Year	Annual Solid waste (Gg/year)	Net annual methane generation by default method
2020	710	10,616
2021	723	11,000
2022	737	11,431
2023	753	11,927
2024	770	12,490
2025	790	13,122
2026	810	13,820
2027	832	14,582
2028	855	15,403
2029	880	16,281
2030	904	17,213
2031	930	18,199
2032	956	19,236
2033	983	20,327

According to Table 3, methane gas emissions from 710 Gg of solid waste amounted to 10,616 in 2020. However, based on projections, solid waste will amount to 983 Gg yearly by 2033, representing a 40% go up? Meanwhile, methane gas emissions are expected to increase, reaching an average of 20,327 tons per year.As illustrated in Figure 2, annual methane gas emissions approximate an inclination curve. When we apply a linear forecast to the estimation data and adjust the curve using the equation (y = 750.13x - 2E+06 with an R2 value of 0.9795), multiple variables influence the upward trend. These parameters include the weather temperature, the carbon ratio in solid waste, and the depth in the dumping site.

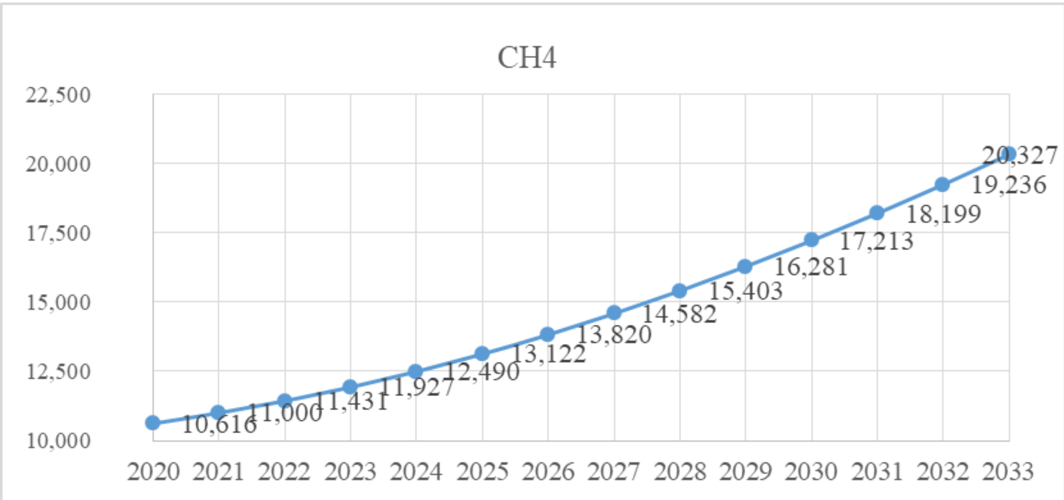

Figure 2. Methane emission from solid waste landfills

Using online sharing to quantify satellite-measured gas emissions: According to Sentinel-5P satellite data, methane concentrations above Erbil clearly increased

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between December 28, 2018, and October 27, 2023—from around 1750 parts per billion to almost 2000 parts per billion. Although this provides a helpful summary, it does not include all of the city's methane sources. The majority of subsequent readings that above the threshold are situated inside the red "excessive" zone, underscoring the gravity of the problem. The graph shows seasonal fluctuations, with summer (June–August) showing greater methane levels and winter (December–February) showing lower levels. These oscillations are probably caused by agricultural practices and temperature-driven microbial activity. The concentration ranged from 1815 ppb in April 2019 to 2078 ppb in August 2023. There is no discernible effect of the COVID-19 shutdown, with the exception of a little decline in April–May 2020 that could have been caused by seasonal reasons.

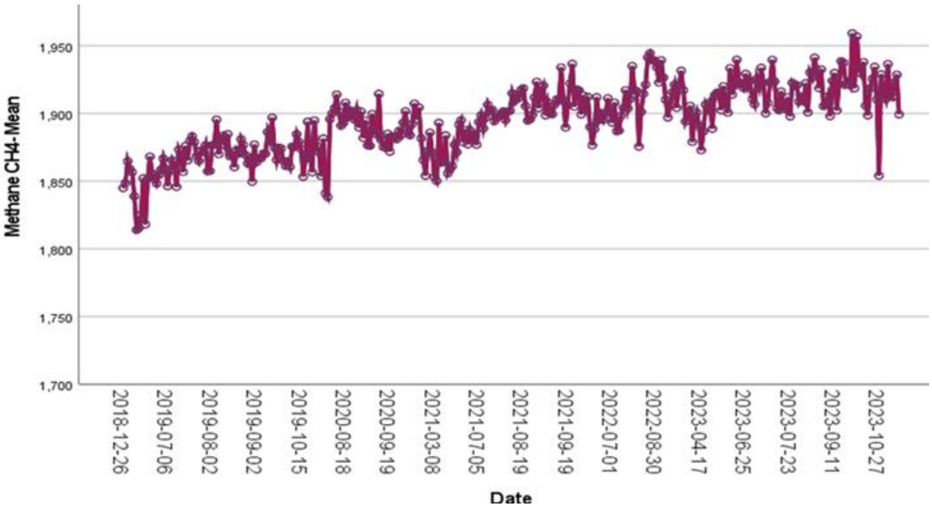

Figure 3. Methane gas data from Copernicus Open Data Hub

A five-year histogram of 353 methane concentration observations with an average of 1894.5 ppb is displayed in Figure 4. Although there are a few outliers, most likely from transient occurrences like gas leaks or agricultural activities, the data is closely grouped around the mean, suggesting consistent levels.

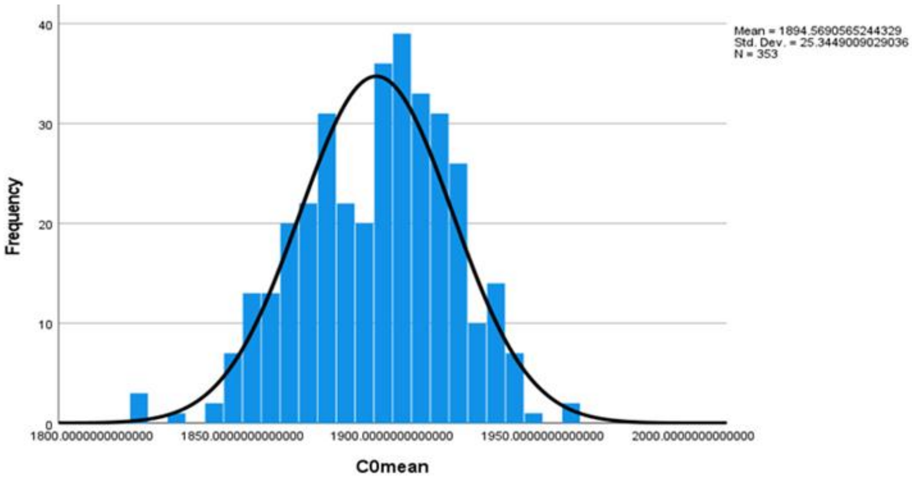

Figure 4. Summarizing methane concentration data

Methane emission from landfill area

As shown in Figure 5A, satellite imagery, such as that available on Earth.JPL.NASA.gov discovered alarming levels of methane gas near Kani Qarzala, Iraq. The concentration in this location has been estimated to be as high as 1593 parts per million meters (ppm-m), with distributed around 6.3km² constituting a

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serious environmental danger. However, in accordance with recognized safety guidelines, allowable methane concentrations should not exceed 1500 ppm, this problem is likely compounded by poor management of local waste disposal sites, which could result in significant rises in methane concentrations over time. Data from Figure 5B collected after April 25, 2023 show a disturbing pattern of rising methane concentrations in the area. When compared to prior readings, the methane plume appears to have extended distributed around 26.768km² as well as intensified, reaching dangerous levels exceeding 3471 ppm. This figure is more than double the recommended safety threshold, prompting severe concerns about the potential. Massive amounts of methane function as a powerful greenhouse gas, facilitating climate change. They additionally have the potential to destroy vegetation as well as disturb aquatic ecosystems, and High amounts of exposure can cause headaches, dizziness, nausea, and breathing difficulties. It can cause unconsciousness and even death under serious circumstances.

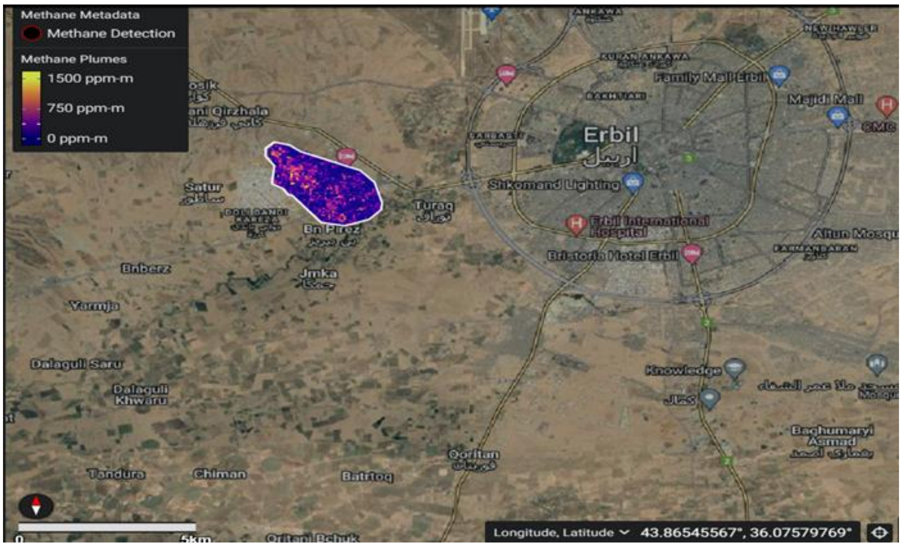

Figure 5a. Detection of gas methane in the Erbil land waste area prior to April 25, 2023

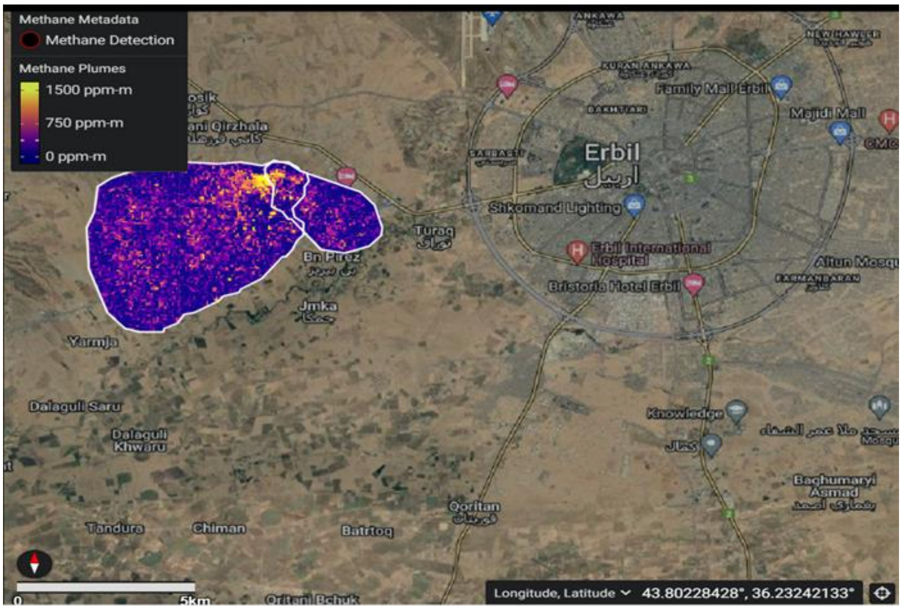

Figure 5b. Detection of gas methane in the Erbil land waste after to April 25, 2023

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Switch the dump location to forrest

To identify hazards and environmental consequences, a comprehensive site assessment is the first step in the landfill closure process. A comprehensive strategy is then put into action, which includes putting in gas collecting systems, capping with impermeable materials, and putting erosion controls in place. Continuous safety is guaranteed by post-closure monitoring. Coordination with authorities, community involvement, and adherence to regulations are essential for success. This multi-step strategy strives to reduce potential environmental dangers, safeguard public health, and provide the location a safe and sustainable environment (Brunner, 1971). To effectively reduce methane emissions in Kane Qrzhala, the region must be transformed into a vibrant green zone. This endeavor necessitates strategic tactics such as:

a- Soil Regeneration: Soil Remediation, replace deteriorated soil with healthy, nutrient-rich alternative, Topsoil Application: Add a layer of clean, acceptable topsoil to create a strong foundation for plant growth. (Grifoni, et al. 2022).

b- Water Security: Installation of an Irrigation System: Establish a reliable water supply to sustain plants, especially in dry situations.

c- Plant Identification Strategy: Tolerant of drought Types, prioritize trees and plants that can thrive in hot, dry areas.

We can establish a flourishing green sanctuary in Kane Qrzhala by applying these methods, which actively decrease methane emissions, supporting a healthier and more sustainable ecosystem (Khan, et al. 2021).

Trees to plant in a dumping area

The choosing of appropriate kinds of trees for planting in a dumping area is critical for the efficient restoration of the eco system. Although the existing location has burning summers and disturbed soil from debris, according to numerous investigations, planting certain selected trees having sufficient resistance to such situations:

a- Tall Trees and Shrubs: Trees noted for their adaptability to harsh settings, such as Pinus thunbergii Parl. and Thuja orientalis, were highlighted (Song, 2018).

b- Adapted Species: The appropriate selection of organisms that are adapted to habitat circumstances improves the effectiveness of restoration. Determining the right mix of kinds of trees adapted to the circumstances of the dumping field is critical for effective restoration (Pietrzykowski, 2019).

c-Survival Rate and Wood Content: Studies have been conducted to analyze the survival rate, parameters, and wood characteristics of trees such as black locust, ash-leaf maple, common maple, and American ash. The performance of these trees in coal ash reclamation was investigated (Szadek, et al. 2023)

d- Additionally, Willows thrive in regions with plenty of water because to their tough roots and need for moisture. They are critical in restoring equilibrium to habitats that are stressed by excess water, and certain pine trees are additionally remarkably adaptable to saturated soils. They thrive in areas where other vegetation could fail due to their resistance to waterlogging, moreover The Bald Cypress, known for its fondness for marshes and soils that are not well-drained, thrives in situations with plenty of water. It exemplifies nature's ability to not only survive but prosper in the face of adversity (Szadek, et al. 2023, Krauss, et al. 2009). The default method's results and satellite data verify that there is a significant methane emission problem at Erbil's waste dumps. A NASA picture emphasizes the urgency, which is exacerbated by climate change and population increase. Methane emissions rise with rising temperatures, particularly during the hottest

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months. A powerful greenhouse gas that absorbs more heat than CO_2, methane has had a significant role in global warming (IEA, 2022). It causes ground-level ozone, which damages agriculture, ecosystems, and respiratory health (UNEP, 2024). Sea level rise, heat waves, droughts, floods, lower crop yields, and health hazards are some of its more widespread effects (CCAC,2024). In order to safeguard the environment and public health, these results highlight the necessity of an inventive methane mitigation plan in Erbil.

CONCLUSION

The research we're conducting used two techniques: the IPCC Guidance 1996 and online sharing for satellite-measured gas emissions. The investigations found dangerous quantities of methane gas at the Erbil trash dumping site, with an annual increase expected until 2033. Organic material content and climate change both had an impact on rising methane levels. Furthermore, studying satellite-measured gas emissions in the Kane Qrzhala dumping site over a 5-year period revealed an unsettling pattern. The methane plume, which was analyzed for the amount present, covered an area of 26.768 km2, breaking safety criteria at a dangerous 3471 ppm—double the permitted level. Immediate action is required to prevent these toxic emissions, given their detrimental effects on temperature rise and the formation of ground-level ozone, which pose major concerns to respiratory health, crop loss, as well as environmental damage. This proposal is for switching the waste site to a green space or woodland, along with the planting of robust plants appropriate for the soil and climate. This novel method is critical for mitigating the far-reaching consequences of methane emissions, which include heatwaves, droughts, floods, rising sea levels, disruptions in plant and animal life procedures, reduced harvests, and increased health risks from extreme conditions. To summarize, immediate environmental protection measures are required to address the imminent threats to both the ecology and public health in Erbil.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

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Iraqi Journal of Agricultural Sciences –2026:57(1):1-18
P-ISSN: 0075- 0530/ E-ISSN: 2410-0862
DOI:

الحد من انبعاثات غاز الميثان من موقع تفريغ النفايات في أربيل: نهج قائم على نظم المعلومات الجغرافية للكشف والتحويل إلى منظر طبيعي أخضر

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المستخلص

يستخدم هذا العمل تقنية نظم المعلومات الجغرافية (GIS)، وخاصةً ArcMap، لمعالجة المشكلة البيئية الخطيرة المتمثلة في تسرب غاز الميثان (CH_4)من موقع مكب نفايات كانه قرزلة، في مدينة أربيل، عند خطي عرض 36°10'23"–36°52'25" شمالاً وخطي طول 43°35'32"–44°23'43" شرقاً. يهدف هذا البحث إلى تحديد وتحليل تركيزات غاز الميثان في محيط موقع المكب، مما يوفر بيانات مهمة لتقنيات الرصد البيئي والتخفيف من آثاره. "تعتمد هذه الدراسة نهجاً متكاملاً يجمع بين البيانات المكانية وصور الأقمار الصناعية. تم استخراج مستويات انبعاثات غاز الميثان من منصتين متاحتين للعامة:earth.jpl.nasa.gov وdataspace.copernicus.eu، بالإضافة إلى قياسات أرضية لرسم خرائط انبعاثات الميثان وتحديد كميتها. تُسهم النتائج في فهم التوزيع المكاني لانبعاثات غاز الميثان، مما يُمكّن من اتخاذ تدخلات مُستهدفة للحد من الضرر البيئي. علاوةً على ذلك، يبحث البحث في بدائل مستدامة للحد من انبعاثات الميثان من خلال تحديد ضرورة تحويل موقع مكب النفايات إلى منطقة خضراء، وفي نهاية المطاف، إلى غابة. امتدت سحابة الميثان على مساحة 26.768 كيلومترًا مربعًا بتركيز 3471 جزءًا في المليون – أي أكثر من ضعف حد الأمان – مُشكلةً خطرًا بيئيًا وصحيًا جسيمًا، وتتطلب اتخاذ إجراءات عاجلة للسيطرة على الانبعاثات. إلى جانب الحد من غاز الميثان، تشمل فوائد تحويل موقع المكب إلى مساحة خضراء تحسين جودة الهواء، وزيادة التنوع البيولوجي، وإنشاء منطقة ترفيهية مجتمعية. وأخيرًا، لا تقتصر هذه الدراسة على توعية الناس بانبعاث غاز الميثان من مواقع التخلص من النفايات فحسب، بل تدعو أيضًا إلى تحويل هذه المواقع إلى مناظر طبيعية مفيدة للبيئة.

الكلمات المفتاحية: غاز الميثان، موقع تفريغ نفايات أربيل، منطقة خضراء، بيئي.