Received: 15 March 2022 | Revised: 25 April 2022 | Accepted: 06 May 2022
DOI: 10.22034/ecc.2022.334227.1379

Eurasian Chemical Communications
SAMI

FULL PAPER

Impacts of greenhouse gas emissions on ambient air quality in kwashe municipal solid waste landfill in Kurdistan region, Iraq

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The aim of this study is to estimate the evolution of some greenhouse emissions from Kwashe municipal solid waste landfill in Kurdistan Region, Iraq. The emission of gasses as CH_4, CO_2, CO, O_2, O_3, and H_2S from the landfills in three sites was measured by the Drager multi-gas detector X-am 5600. The formation of CH_4 inside the landfill body is spatial according to the load of the buried organic waste, the degree of organic waste moisture content, the spatial pH, and temperature within the landfill body, and further found to be higher thousands fold over its over save ranges in the third site. The liberation of CO_2 is greater than its normal background in the atmosphere as 0.03% in three sites, especially in the third site to reach its risk level and at least hundred times greater than the normal ranges of carbon dioxide in the atmosphere. These reflect the high load of organic waste greater than the half and most of decomposition is carried by aerobic respiration. CO level in site 3 recorded the highest values in the first week and remained over the normal range till the end of investigation. The ozone formation ranges between 0.01 to 0.05 ppm and there is a parent difference between the sites. The highest emissions of H_2S were noticed in site 3 and the peak was recorded in the first week of observation at 5 ppm. Then, the liberation continued after 4 weeks to 8 weeks, indicating that the load of wet organic waste deposition is concentrated on site 3.

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KEYWORDS

Landfill; methane; carbon dioxide; hydrogen sulfide; ozone.

Introduction

The Landfill management has traditionally focused on gas and leachate control, both to improve waste decomposition and to limit the emissions of aqueous contaminants such as methane and hydrocarbon trace gases, which contribute to the creation of the urban ozone. Landfill gas is a biogas made up of around 45-60 percent (v/v) methane (CH_4), 45-60 percent (v/v) carbon dioxide (CO_2), and traces of numerous additional compounds produced by anaerobic microbial activities in landfills [1-5]. Landfill gas further contains trace amounts of oxygen (0.1 to 1 percent), hydrogen (0 to 0.2 percent), and nitrogen (2 to 5 percent) from the atmosphere, as well as carbon monoxide (0 to 0.2 percent), sulfides (0 to 1 percent), ammonia (0.1 to 1 percent) from the waste, and many trace components (0.01 to 0.6 percent) generated by biotic or abiotic processes within the landfill or which have been directly volatilized from the waste [6].

CH_4 and CO_2 are the most important human greenhouse gases (GHGs), with CH_4's global warming potential 20-28 times that of CO_2 over a 100-year time frame [5,7,8]. The major gases involved in biological waste decomposition are methane (CH_4), carbon dioxide (CO_2), hydrogen (H_2), and oxygen (O_2). The other gases, such as N-compounds, volatile organic compounds, and others are also regularly created, including the unwelcome carbon monoxide (CO) and hydrogen sulfide (H_2S). With a contribution of 49 × 10^9 tons CO_2 per year in 2004–2005, the post-consumer waste sector is expected to contribute to 3–4% of total global anthropogenic GHG emissions [9]. Methane, nitrous oxide, and carbon dioxide are well-known greenhouse gases (GHGs) which have a direct impact on the radioactive forcing of the Earth's atmosphere. Carbon monoxide even has an impact on the Earth's radioactive forcing, both directly and indirectly, through absorption and emission of the reflected infrared radiation, as well as chemically modifying the abundances of methane, ozone, and carbon dioxide [10].

The reduced S gas emissions from landfills, such as H_2S, can be an olfactory nuisance and a potential health danger for nearby residents in some cases. The impact of gypsum wallboard in building and demolition wastes, high S geological locations, and high sulfate local cover soils on the formation of sulfide gases from landfills [11,12], as well as on assimilatory or dissimulators reduction of sulfate and sulfite produces H_2S has been studied for decades [13,14]. The assimilatory production is carried out by a huge number of microbial species, resulting in the integration of sulfur into organic components. Dissimulators reduction is performed by only a few species, particularly the completely anaerobic sulfate reducers. H_2S is a gas which can be found in both natural gas and groundwater. It is also known as sewer gas and a waste breakdown product, as well. Byproducts of methanotrophic oxidation of landfill gas (LFG) or oxidation of organic carbon present in soil components in landfill cover soils include carbon dioxide and monoxide [15].

Carbon emissions have continued to increase to 34 Gt CO_2 per year since the Kyoto Protocol baseline year of 1990 [16]. This trend has raised fears that countries may be unable to reach the necessary carbon reduction goals in order to meet the Paris Agreement's 2 °C target [17]. While CO_2 and CO are often not included in landfill emissions inventories due to ambiguities in their source (i.e., trash mass vs. cover soils) [18], both gases were measured in this study, and data and analysis are presented both with and without these two gases. CO has a slight direct radioactive forcing; however, its indirect forcing is greater, resulting in the generation of ozone or oxidation to carbon dioxide, as well as a drop in methane loss rate [19]. Although the biological synthesis of CO is unknown, investigations have revealed that methanogens actively produce CO during exergonic methane creation from carbon dioxide and hydrogen [20]. Researchers found the detrimental effects of Kwashe municipal solid waste landfill leachate effects on the chemical properties in surrounded area in Iraqi Kurdistan region. Likewise, they found huge pollution of soil by crude oil and their derivatives all over Kwashe industrial area in Iraqi Kurdistan region [21]. Therefore, the aim of this study is to estimate the quantity and impacts of most causing global warming and climate change gasses like CH_4, CO_2, CO, H_2S, and O_3 emission on the quality of the ambient air from Kwashe municipal solid waste landfill in Iraqi Kurdistan region.

Material and methods

Study area

As displayed in Figure 1, the studies were conducted in Kwashe municipal solid waste landfill within Kwashe industrial area in Iraqi Kurdistan region. Kwashe is an industrial area in Summel District which far about 20 Km west of Duhok City. This area is located between latitude 36.9906°N longitudes 42.7894°E [22,23].

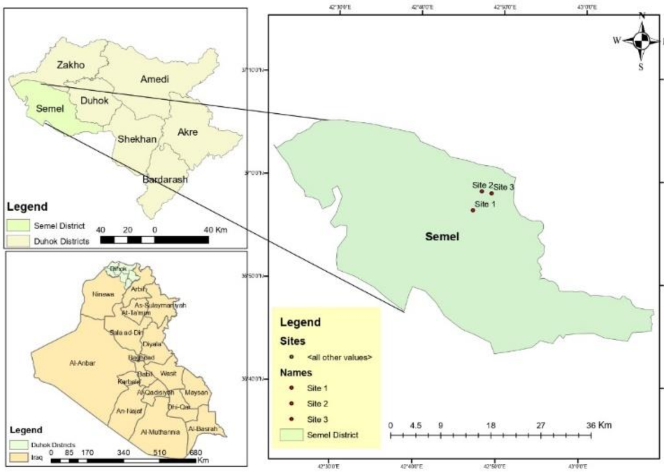

FIGURE 1 The location of Kwashe industrial area and landfill of three sites of gas measurements in Kurdistan Region, Iraq

In Kwashe industrial area, there is a material recovery facility (MRF) that receives approximately 900 to 1000 tons of municipal solid waste of which about 50-60% is organic food waste. After waste separation, about 50-60% of the waste is thrown into an open landfill in a nearby valley with no separation and treatment, because the load of municipal garbage is more than the capacity of waste separation factory, and thus a huge amount of these waste is thrown directly to the open landfill, as depicted in Figure 1. Therefore, the emission of the greenhouse gasses from landfill is suspected to be high as most of these organic wastes undergo the aerobic and anaerobic decomposition of indigenous soil microbes in the landfill site.

Measurements of greenhouse gas emission from landfill

The emission of gasses as CH_4, CO_2, CO, O_2, O_3, and H_2S from landfill in three sites were measured for 8 weeks from 20.09.2021 to 18.11.2021 by the Drager multi-gas detector X-am 5600, as demonstrated in Figure 2. The gas detector Drager X-am 5600 is used to detect the flammable gasses with single-handed operation in tough industrial environments and works in optimal functionality even under harsh conditions for a broad variety of toxic gasses which need to be measured simultaneously and require a regular calibration for accuracy.

FIGURE 2 Drager multi-gas detector X-am 5600 device

Result and discussion

The emission of heat trapped gasses like CO_2, CH_4, and N_2O from aerobic and anaerobic degradation of municipal solid organic waste and its leachate treatment facilities is considered the most serious source of air pollution, increasing the threat of global warming and climate change, of which one ton of organic waste buried in landfill produces 50 kg methane [24]. Landfill contributes to about 5% of the total greenhouse gases emissions around the world and these GHGs are increased 1.5% annually [25]. Methane gas is the second heat trapping gas after CO_2 which causes the global warming, the climate change, and is 28-36 times more effective than CO_2 in trapping heat, and also leads to the ozone formation at ground level of troposphere which has negative effects on ecosystem and human well-being [26]. The normal atmospheric concentration of CH_4 was 700 ppb or 0.00007% in the pre-industrial area and increased to 1789 ppb in 2007, at an increasing rate of 0.34%/yr or 2.7 ppb/yr. According to the studies, methane gas which released from landfill around world contribute to 1–2% of the total greenhouse gases emissions [27]. When organic waste is initially introduced to the landfill, the aerobic bacteria decompose it aerobically, producing largely carbon dioxide gas for about a year. After that, the anaerobic conditions develop in the landfill, which methanogenic bacteria prefer to convert most of the organic waste to methane gas. As presented in Figure 3, the concentration of methane around Kwashe land fill is not stable during 5 weeks of investigation and varies from site to site. In the first site, it's in normal and safe range, while in the second site, it increased slightly over its save range, while it increased higher thousands fold over its over save ranges in the third site. This finding reflects that the occurrence of an anaerobic condition which leads to the formation of CH_4 inside the landfill body is spatial according to the load of organic waste buried and organic waste moisture content, and also to the spatial pH and temperature within the landfill body. As indicated previously, Kwashe landfill receives roughly 1000 tons of MSW and the other half of this organic waste, 250-300 tons, is put directly into landfills, where it produces 1.25-1.5 tons of methane every day and roughly the same amount of CO_2 during 30-50 years of anaerobic and aerobic decomposition. While for each ton of organic waste, if properly used in anaerobic digester, it can produce 300 m^3 clean biogas which can be bottled to use in cooking and heating [28]. Research confirmed that the produce of methane by livestock is more 40% than of produced by transportation and the emission of excess methane by landfills will worsen the situation [29]. The best solution for treating landfill gas (LFG) can be used as a renewable clean energy, especially methane, by its capturing and collecting through vacuumed vertical and horizontal pipes buried in MSW landfill to be later processed, to be used as source of clean fuel for various purposes, and to minimize air pollution, pungent smell, smog, fires, and the global warming issues. LFG further can be used in evaporating the leachate of landfill to make it most concentrated and easy for handling [30].

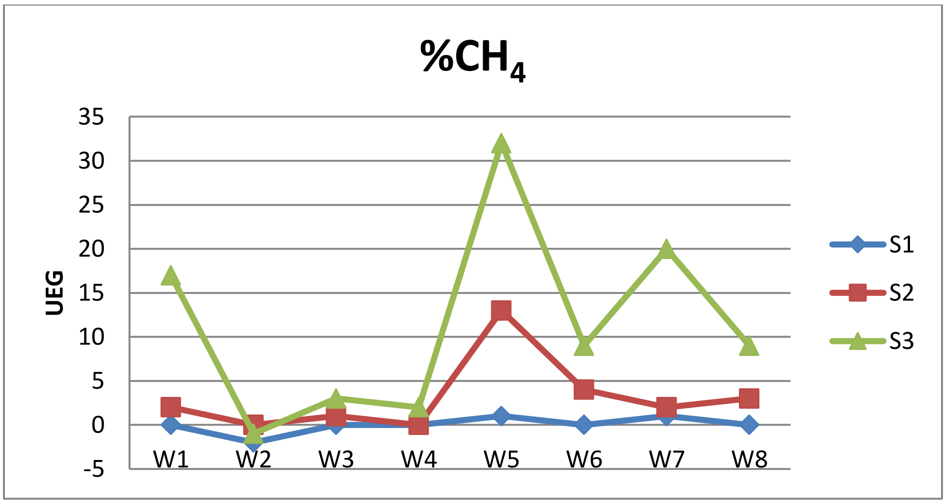

FIGURE 3 Emission of CH_4 in Kwashe landfill for 8 weeks from 20.09.2021 to 18.11.2021

Carbon dioxide is considered the major waste of our present civilization and the first causes of global warming and climate change, as well. Its normal range in atmosphere is 0.003% which equal approximately to 280 ppm in pre-industrial area, in that concentrations CO_2 beside water vapor in atmosphere kept our planet temperature around 13 ºC, otherwise it will be frozen to -17 ºC. Recently, its level has been increased by 50% from preindustrial era to reach 425 ppm to cause an increase at the earth temperature about 1 ºC in last century and bring drastic changes in climate changes [31]. The burning of fusel fuel in industries and transportation is the major sources of surplus CO_2 in the air and about 9 billion tons of fossil carbon as fuel are burned annually around the world to produce surplus 30 billion tons of CO_2. Less potent and original sources of its emissions are aerobic breakdown of organic waste by soil and water microbes, and the spontaneous breathing of creatures [32]. The additional emission of CO_2 by creating more landfill site and burning the huge amounts of organic wastes will elevate the opportunity of both aerobic and aerobic decomposition which lead to more CO_2 and CH_4 emissions, respectively. CO_2 beside CH_4 make up most landfill gasses about 50% for each gas with a small amount of non-methanogenic compound. The decomposition of the organic landfill material in land fill undergo four phases, the first one is oxygen rich phase when aerobic bacteria are activated and decomposes organic waste and consume the most amount of oxygen to produce the large amounts of CO_2 and hydrogen gas in the second phase, the third phase is called methanogenic non-steady when the CO_2 production declines from the peak and methane gas producers to equalize with CO_2 in the end of this stage and lasted longer than other phases, the fourth phase is called methanogenic steady phase when methane production is fixed at 50-55% and CO_2 at 45-50% from the total gas volume liberated from landfill, while the production of nitrogen gasses reach to its minimal ranges.

As illustrated from Figure 4, the CO_2 concentration is greater than its normal background in the atmosphere 0.03% in three sites in Kwashe landfill, but the level steadily increased from the first site to the third site to reach its risk level and at least hundred times greater than normal ranges of carbon dioxide in the atmosphere. These high evolution rates of CO_2 from landfill reflect the high load of organic waste greater than the half, and also the majority of decomposition is carried by aerobic respiration. The landfills further contribute to a large extent in an increasing atmospheric CO_2 besides the burning of fossil fuels.

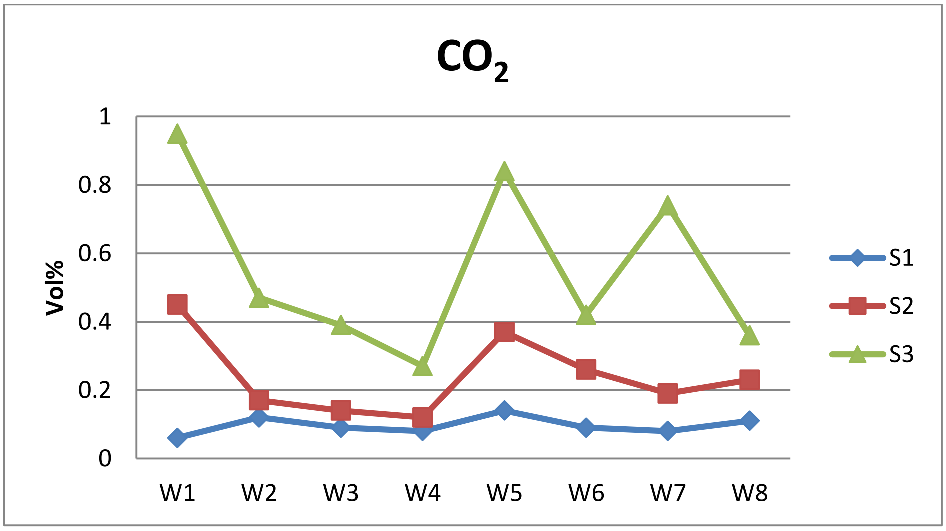

FIGURE 4 Emission of CO_2 in Kwashe landfill for 8 weeks from 20.09.2021 to 18.11.2021

Carbon monoxide is highly toxic for human being as it causes suffocation, because it has the same chemical behavior of oxygen in the bloodstream. CO is used as an indicator of landfill fires as it produced mainly from an incomplete combustion of plastic material in the landfill, the acido-genesis, the methanogenesis during anaerobic decomposition of organic waste in landfill body, and from methane oxidation in the air, its normal range in air reach 0.8 ppm, while this level usually increased in the ambient air in landfill area up to 150 ppm. Figure 5 illustrates that the CO level in ambient Kawshe landfill air is within the normal range in the first site during 8 weeks of investigation, and in the second site, it increased over the saved range after week 4, but not to the risk level. While in site 3, the highest value was recorded in the first week and remains over the normal range until the end of investigation. These high levels of the emitted gasses from the third site return to the occurrence of anaerobic veins in landfill body and high wet organic load on this site.

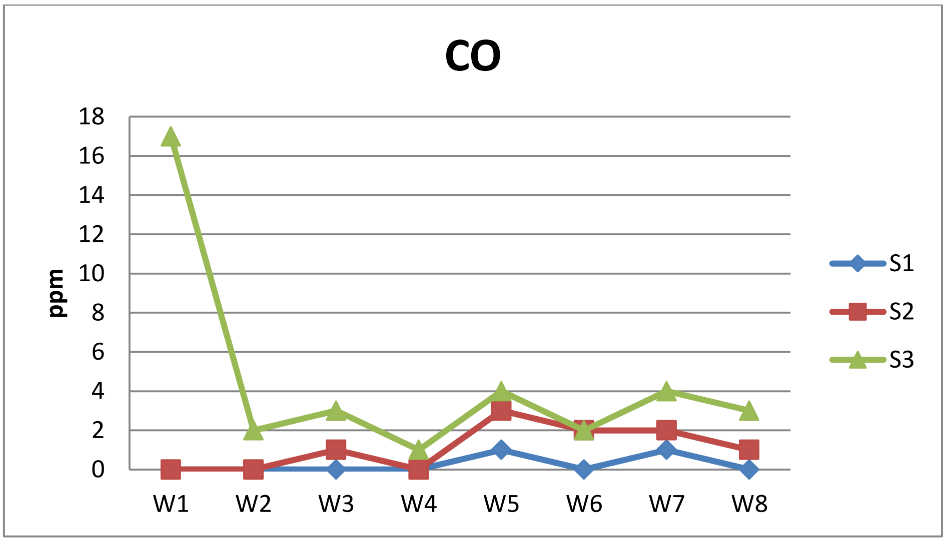

FIGURE 5 Emission of CO in Kwashe landfill for 8 weeks from 20.09.2021 to 18.11.2021

Oxygen as the most beneficial gas for almost organism respiration and used as an electron accepted in metabolism pathway. Hence, oxygen is required for aerobic microbial decomposition of organic waste and the majority of decomposition within the landfill body is carried by oxygen consumption in this process to produce huge amounts of CO_2 approximately 40-60% from landfill produced gasses; therefore, it is declined to form only 0.1-1% from landfill gasses. When oxygen is depleted from landfill body, the process of anaerobic decomposition will convert it mainly to CH_4 gas which comes as a main constituent of landfill gasses for 45-60%. As depicted in Figure 6, oxygen in ambient air in landfill fluctuate around its normal ranges as 21% in both the first and the second sites, while in the third site, it reduced even to 18% indicating that the microbial activity and decomposition rate is significantly high in this site.

Ozone gas usually found in high level in ambient landfill air as it created from the evaluation of nitrogen oxides, methane, hazardous air pollutant (HAP), volatile organic compound, formaldehyde, carbon monoxide from the decomposition, and fires from landfills sites in the presence of the sunlight [33]. Although ozone gas is extremely valuable in the stratosphere and the upper atmosphere because it absorbs the majority of harmful UV-B and UV-C and converts it to thermal energy, it further protects our planet from harmful effects such as photosynthesis disruption, skin cancer, cataracts, and immune system destruction. However, the increase of the ground level in troposphere and known as smog has harmful effects as its chemical reaction with lung tissues reduce its function and causes cough, throat irritation, chest pain, asthma, and disrupt photosynthesis in crops and trees. As depicted in Figure 7, the ozone formation in the landfill ambient, the air ranges between 0.01 to 0.05 ppm and there is a parent difference among the sites, both in the second and the third sites, a high level of ozone formation is recorded as it would depend on the evolution of other potent pre-secures of O_3 as methane and carbon monoxide; however, it neither reach the risk level, nor the USEPA guidelines of the ambient atmospheric ozone concentration as 2,35 micrograms/ m³.

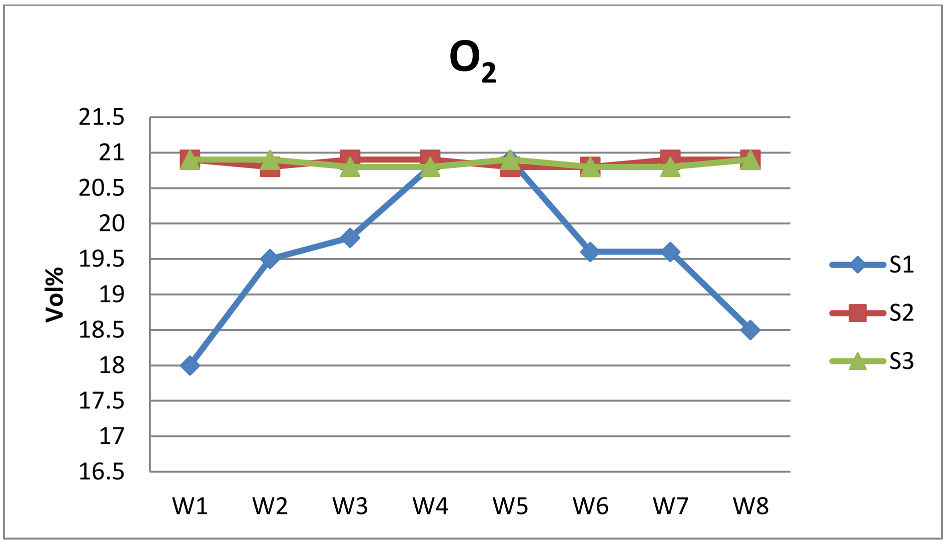

FIGURE 6 Emission of CO in Kwashe landfill for 8 weeks from 20.09.2021 to 18.11.2021

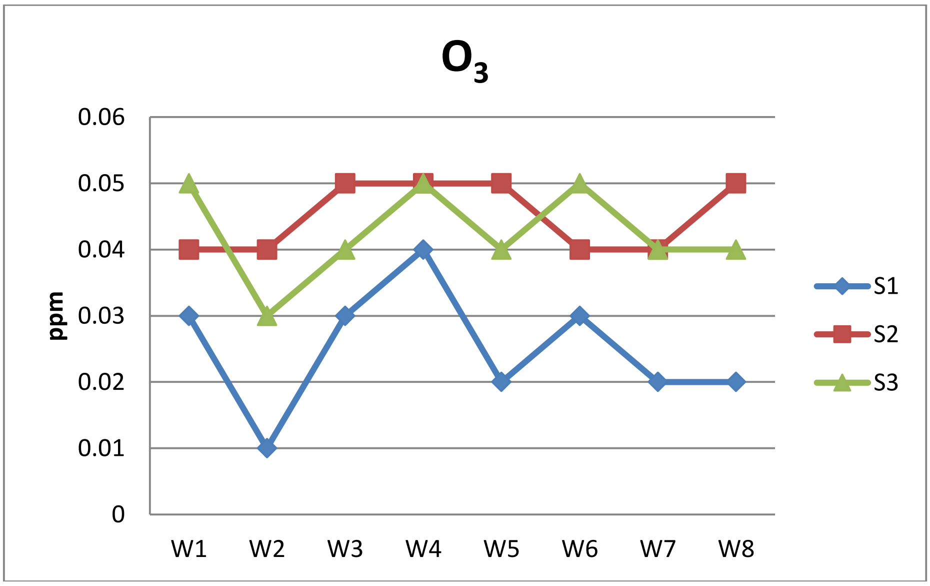

FIGURE 7 Emission of O_3 in Kwashe landfill in for 8 weeks from 20.09.2021 to 18.11.2021

Hydrogen sulfide gas is one of the most concerning produced gases from landfill sites since it is linked to the foul odor of the landfill as well as a number of other health and environmental issues such as toxicity to animals and plants, and causes some problems in paddy rice fields. H_2S is formed during sulfur cycle and the soil bacteria play an essential role in its creation beside the presence and absence of oxygen and moisture.

In landfills, hydrogen Sulfide gas is primarily produced by the breakdown of sulfur-containing organic material such as the sulfonate (-SH) group in protein, in which amino acids are transferred to inorganic sulfur substances or to H_2S as a result of rotten eggs odors, and gypsum $CaSO_4$ containing material such as wall boards and sheet truck that are thrown in landfill will exacerbate the situation and increase their creation, particularly during rainy seasons which create anaerobic situations. H_2S in landfill sites mainly result from the anaerobic decomposition by proteolysis bacteria which decompose protein like *Clostridia, Villanella* and organic matter containing S amino acids such as cysteine, cystine, and methionine. Because it is heavier than air, it moves near landfill ground, so gives rotten eggs smell to the landfill site, the wind speed, and direction effects on its dilution. Sulfate reduction is further made a considerable source of H_2S in landfill sites. It is reduced by strict anaerobes, sulfur purple, and green bacteria and from the cytogenesis stage of organic waste degradation rich in sulfur compounds.

$$SO_4^{=} + \text{organic compounds} \longrightarrow S^{=} + H_2O + CO_2$$
$$S^{=} + 2H^{+} \longrightarrow H_2S$$

As displayed in Figure 8, the H_2S release from Kwashe landfill is negligible the first site except 1 ppm was emitted in week 3. In the second site, the H_2S emission was noticed after 4 and 5 weeks. The highest H_2S emissions were noticed in the third site and the peak is recorded in the first week of observation at 5 ppm. Then, the emission was continued for another 4 to 8 weeks, indicating that the wet organic waste deposition load is focused on the third site.

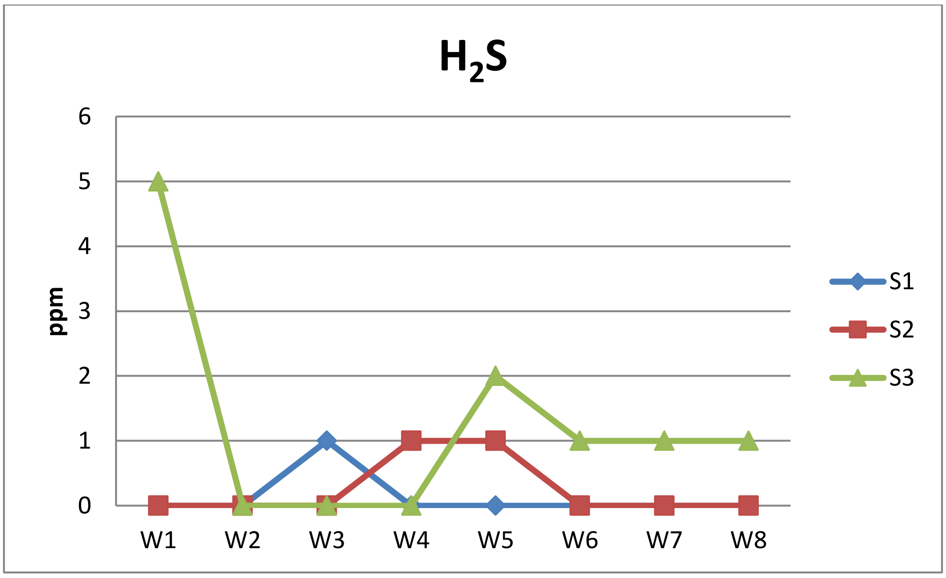

FIGURE 8 Emission of H_2S in Kwashe landfill for 8 weeks from 20.09.2021 to 18.11.2021

Conclusions and recommendation

It concluded that Kwashe solid waste municipal landfill contribute to a large extent in the the ambient air pollution by hazardous air pollutants such as methane, hydrogen sulfide, etc. Furthermore, both quality, quantity, and moisture content of the organic waste and rainy seasons play a major role in increasing the amount of gas emissions from landfill. Emission of these gasses leads to the formation of other hazardous gasses like ground level ozone and particulate matter. Moreover, this landfill causes large soil losses and erosion used for waste burial. As a recommendation, the Kwashe solid waste, municipal landfill can be used for natural gas and energy production, if it reconstructed scientifically by inserting the system of gas collection pipes to the large landfill body. To minimize the emission of gasses from Kwashe solid waste and the municipal landfill, it is recommended to separate the organic waste before being thrown into the landfill in order to be used in other beneficial aspects such as compost production.

Acknowledgements

This research was supported department of Biology and Environmental Sciences, College of Sciences, University of Zakho.

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How to cite this article: Najmaldin Ezaldin Hassan, Mustafa Ismail Umer*. Impacts of greenhouse gas emissions on ambient air quality in kwashe municipal solid waste landfill in Kurdistan region, Iraq. *Eurasian Chemical Communications*, 2022, 4(10), 1012-1021. **Link:** http://www.echemcom.com/article_150798.html