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Solid Waste Landfills as a Source of Green Energy: Case Study of Al Akeeder Landfill

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Abstract

The purpose of this paper is to estimate the amount of methane emitted from Al Akeeder landfill which is the second largest landfill in Jordan. To achieve that Gas-Sim model was used in predicting the amount of methane emissions. It was found that the methane emission will reach its peak value of 12 Million M^3/year by the year 2021, one year after the landfill closure. Furthermore, the power that can be obtained from the landfill in case ob methane recovery was estimated to be 5.6 MW in 2021. Utilizing the biogas will not only generate a green energy, but also will create a source of revenue through selling the CERs regulated by Clean Development Mechanism of Kyoto protocol.

Keywords: Landfills; AL Akeeder; Green Energy; Power; Greenhouse Gases.

1. Introduction

Landfills are remaining and will remain a common method for landfill disposal (Abu Qdais, 2007). Unless properly managed, landfills will pose serious environmental and health risks. Several gases are generated by decomposition process of organic materials in a solid waste landfill. The composition, quantity, and generation rates of the gases depend on several factors such as refuse quantity, density and composition, placement characteristics, landfill depth, refuse moisture content, temperature and amount of oxygen present (ASTDR, 2006) . Three processes form landfill gas, these are: bacterial decomposition, volatilization and chemical reactions. Table 1 outlines a typical landfill gas composition (El Fadel et al. 1997). It can be observed that methane forms the highest fraction of gases emitted from the landfill, followed by carbon dioxide.

Table 1. Typical Landfill Gas Composition (El Fadel, etal 1997)

Component	Concentration range (%)	
	Lower Limit	Upper Limit
Methane	40	70
Carbon dioxide	30	60
Carbon monoxide	0	3
Oxygen	0	5
Nitrogen	0	3
Hydrogen	0	5
Hydrogen sulfide	0	2
Trace compounds	0	1

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1.1. Health Impacts

Gases generated in landfills normally take the shortest or easiest route to the surface. Occasionally; the presence of fissures in or surrounding the filled land, possibly together with the presence of surface barrier will cause the evolved gases to travel large distances horizontally. In some cases, these gases found their way into basements of houses and buildings and deaths and injuries have resulted from asphyxiation, poisoning or from detonation of explosions of air methane mixtures. Numerous incidents of fires and explosions due to lateral gas migration away from landfills have been reported in the literature. (El – Fadel, 1997, Blumberga,2001)

Although landfill gas, rich in methane, provides an energy recovery opportunity, it has often been considered to be a liable because of its flammability and ability to form explosive mixtures with air in concentrations from 5 to 15 % by volume. Methane has the tendency to migrate away from the landfill boundaries by diffusion and advection. Diffusion and advection rates depend primarily on the physical properties and generation rates of the landfill gas, refuse permeability, internal landfill temperature, moisture content, surrounding soil formation and changes in barometric pressure.

1.2 Environmental Impacts

Emissions of methane and carbon dioxide from landfill surfaces contribute significantly to global warming or the greenhouse effect. Methane has received recent attention as a contributor to global warming because on a molecular basis, it has a relative effect 20 to 25 times greater than carbon dioxide, it is more effective at trapping infrared radiation and tends to persist longer in the atmosphere owing to other species (carbon monoxide) with a greater affinity for hydroxyl ions, the oxidizing agent for methane.

Recent increases of methane concentrations in the atmosphere have lead to extensive characterization studies of global methane sources and sinks. Atmospheric methane concentrations were reported to increase at an average rate of about 1 to 2% per year. It is estimated that methane contributes about 18% towards total global warming. This contribution represents 500 million tons per year approximately of which 40 to 75 million tons are attributed to emissions from landfills. Due to continuing trends in population increase and urbanization, solid waste landfills are becoming a significant contributor to atmospheric methane, unless recovery control systems are implemented (El Fadel Etal 1997).

Odors are mainly the result of the presence of small concentrations of odorous constituents (esters, hydrogen sulfide, organosulphurs, alkyl-benzenes, limonene and other hydrocarbons) in landfill gas emitted into the atmosphere. The odorous nature of landfill gas may vary widely from relatively sweet to bitter and acrid depending on the concentration of the odorous constituents within the gas.These concentrations will vary with waste composition and age, decomposition stage and the rate of gas generation and the nature of microbial populations within the waste. Although many odorous trace compounds may be toxic, they have historically been perceived more as an environmental nuisance than as a direct health hazard. The extent to which odors spread away from the landfill boundaries depends primarily on weather conditions; wind, temperature, pressure and humidity (Blumberga, 2001)

2. Al Akeeder Landfill

Al Akeeder landfill is located in the northern region of Jordan, near the main road to Mafraq Governorate. It is part of the Irbid and Mafraq Governorates; located in the boundaries of the Yarmouk Watershed with a Palestinian coordinates of 251° 22' E and 216° 33' N, Figure1. It is located at 27 km to the east of the city of Irbid, just at a distance of 1 km from the Syrian borders. It can be reached by a paved road about 7 km to the north of the Irbid-Mafraq highway. The nearest village is about 1.58 km to the south west called Al Akeeder village. This site was chosen because of low population density, low land cost and to minimize the leakage of contaminants into groundwater. Nowadays; the area near the landfill becomes populated and the impacts of the landfill on the public health and the surrounding environment should be investigated (METAP, 1998, Al Khaldi, 2001, Abu Rukha and Al Kofahi, 2001)

Al Akeeder landfill is the only official dump site for northern Jordan with an area of 806×10^3 m^2 used in almost equal proportions for disposal of industrial wastewater and municipal solid waste, see Figure 3.2. It serves the populations of Irbid city and another 62 villages and cities in Irbid, Mafraq, Jarash and Ajloun Governorates. Although by far the largest disposal site in the northern Jordan, Al-Akaider is not the only one. It is however believed to be the only site in the region which accepts liquid wastes. Municipal solid waste, small quantities of industrial waste and industrial wastewater are disposed of at the site. In the past; municipal wastewater was discharged with industrial wastewater, nowadays; municipal wastewater is discharged directly to a new treatment plant near the landfill [7, 39, 40, 41].

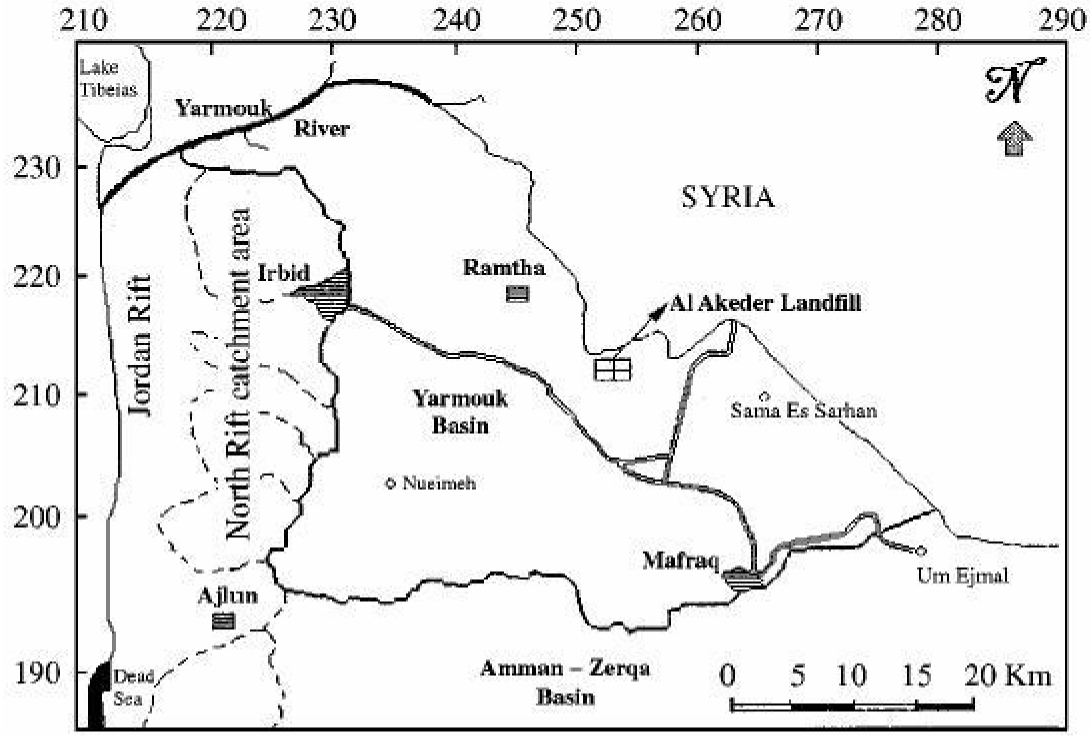

Figure 1. Location of AL Akeeder landfill site in Northern Jordan.

2.1. Solid Waste Composition and Quantities

Precise information on the waste composition disposed in the landfill is not available. Though, a study detained in 2001 shows that the landfilled waste is mostly organic. Figure 2 illustrates the composition and percentages of the solid waste (Chopra et al, 2001).

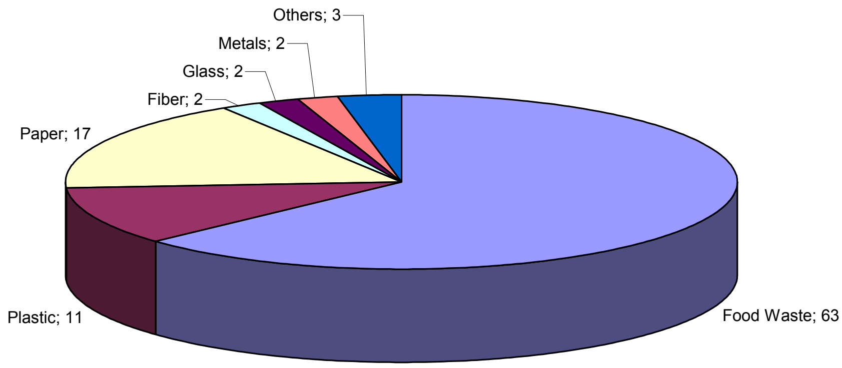

Figure 2. Composition of solid waste disposed at Al Akeeder landfill (Chopra et al, 2001)

Food waste has the highest percentage of total waste with percentage of 63 % while paper has the second highest percentage of 17 %. About 20 % of the waste is non-degradable materials. Industrial waste portion is about 10 % of the waste disposed at the landfill.

The per capita generation rate of municipal solid waste in Jordan ranges from 0.72 to 0.91 kg / capita / day. This range includes the increase of solid waste generation as a result of life changes., Abu Qdais (1987) estimated the daily per capita generation of municipal solid waste in Irbid; his estimates ranged from 0.78 to 0.92 kg/capita/day; which was reasonable and close to that found in literature.

3. Methane Gas Generation from Al Akeeder Landfill

To simulate the methane generation from the landfill, Gas-Sim model was used. Landfill gas generation was simulated from 1981 to 2055. The results of simulations presented in Figure 3

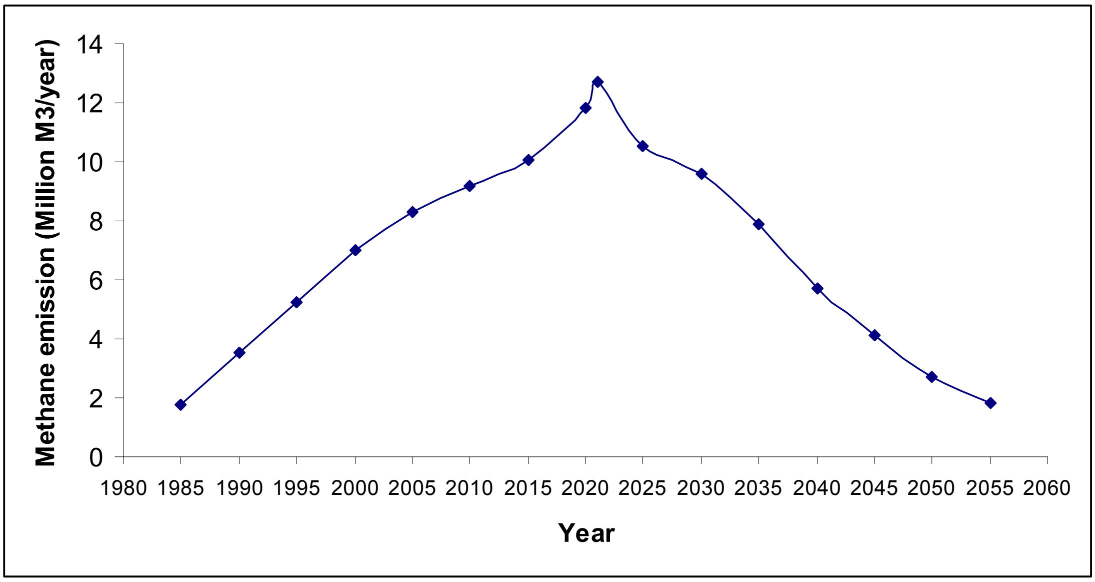

Figure 3. Simulated methane emission from the landfill using Gas-Sim Mode

It can be seen from Figure 3, that the trend of the simulation follows the triangular model theory. In the period from 1985 to 2021; the methane generation increases as well as the waste input quantities. At the beginning of simulation period (1985), the predicted amount of methane generation was found to be 1.75 million M^3/year. By the year 2020, it is assumed that the landfill will be reaching its full capacity and will be closed. Therefore, the peak methane generation will take place one year after the closure, namely the year 2021. The peak amount of methane was estimated to be 12 Million M^3/year. Then the methane production starts declining. This can be interpreted as the landfill enters a stage of stabilization, where methanogenic bacteria starts to produce less methane amounts due to low moisture content and low fresh biodegradable solid waste.

Gas-Sim model is capable of simulation the methane production for 100 years. However; methane generation has been estimated to a period of 35 years after the closure of the facility. The waste input quantity for the study period was entered to the model as a range to account for the uncertainty.

3.1 Power potential of the generated methane

Methane is a well known greenhouse gas. In addition it is a flammable gas with relatively high heat content. To minimize its adverse environmental impacts and make use of the energy recovery, it is assumed that a biogas plant will be constructed at Al Akeeder landfill and will start operation by the year 2015. Assuming the methane recovery of 40% from the emitted methane, the estimated amount of power that can be obtained from such a plant is illustrated in figure 4.

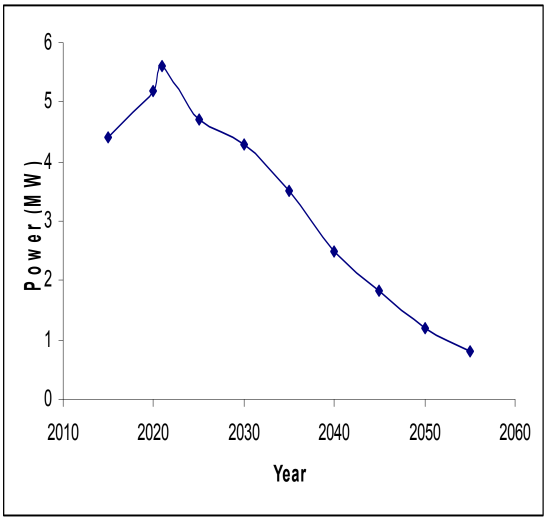

Figure 4. Estimated power that can be obtained from methane recovery at Al Akeeder Landfill.

It can be observed that about 4.3 MW of power can be obtained at the beginning of plant operation, while this value reaches 5.6 MW by the year 2021, directly after the landfill closure.

3.2 Global Warming Potential

Gas-Sim determines the effect of green house gases and compares the effect of each compound to carbon dioxide. For example; methane has 21 times the effect of carbon dioxide. Table 2 shows the species contributing to GWP and their CO_2 equivalence.

It is recognized that methane has the highest GWP (77.22 %) while carbon dioxide contributes to the total global warming potential by 12 %. It is recommended to best exploit the methane as a renewable source of energy and hence reducing the environmental problems resulting from its emission to the atmosphere.

Based on 40% methane recovery the amount of greenhouse gas emission reduction is illustrated in figure 5. It can be seen that by the beginning of the biogas plant operation (2015), the amount of emission reduction is about 62 thousand tons of CO_{2eq}, this amount will reach 80 thousand tons of CO_{2eq} by the year 2021. This suggest the possibility of making use from the Clean Development Mechanism of Kyoto Protocol, by selling the certified emission reduction. Assuming a cost of 12 US$ for each tone of CO_2 , the income from the carbon credit will be about 620,000 US$ in the year 2015 and will reach to about 800,000 by the year 2021

Table 2. GWP Species Emitted from Al-Akaider Landfill in 2006

Species	**GWP (tones of CO_2)**
Methane	150000
Carbon Dioxide	23300
1, 1, 1, 2 – Tetrafluorochloroethane	2.88
1, 1, 1 – Trichlorotrifluoroethane	54.3
1 – Chloro – 1, 1 – difluoroethane	155
Chlorodifluoromethane	4570
Chloroform	0.221
Chlorotrifluoromethane	1280
Dichlorodifluoromethane	13600
Dichloromethane	3.77
Trichloroflurommethane	956
Trichlorotrifluoroethane	325
Total	**194247**

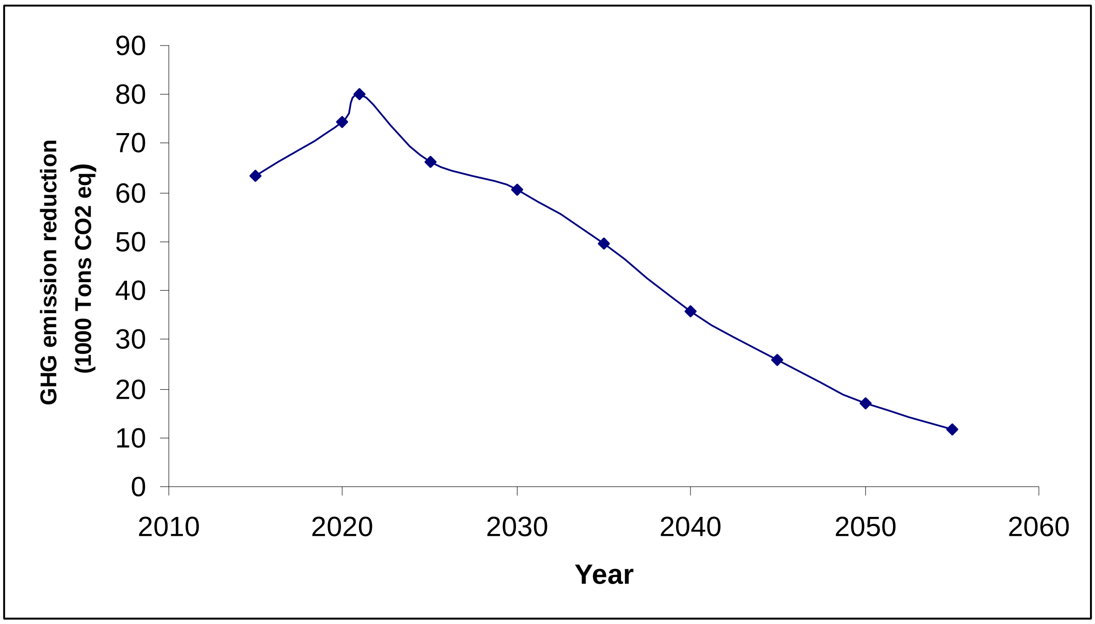

Figure 5. Greenhouse gas emission reduction based on 40% methane recovery

4.Conclusions and Recommendations

Landfills are source of greenhouse emissions. If biogas recovered from the landfill, adverse environmental impacts will be minimized. In addition, clean energy will be produced that will offset the polluting fossil fuel. In this study, methane emissions from AL Akeeder landfill were estimated using Gas-Sim model. It was estimated that the amount of methane that will be emitted by the year 2021 to be 12 Million M^3/year, while the power that can be obtained from the landfill in case of gas recovery will be 5.6 MW. In addition, the amount of greenhouse gas emission reduction will be about 80 thousand tones of CO_2 $_{eq}$ in the that year.

It is recommended to carry out a field study by conducting a pump test, so as to verify the results of methane modeling process.

References

[1] Abu Qdais H. A. Techno Economic Analysis of Municipal Solid Waste Management in Jordan, Waste Management, Vol. 27, 2007, 1666-1672

[2] ASTDR , (2006). Agency for Toxic Substances and Disease Registry (ASTDR). Landfill Gas Primer. An Overview for Environmental Health Professionals. [Online] [Accessed in June 2005]. Available from URL:http://www.atsdr.cdc.gov/HAC/landfill/html/ch2.html

[3] El-Fadel M., Findikakis A., Leckie J. Environmental Impacts of Solid Waste Landfilling. Environmental Management, Vol. 50, 1997, 1–25

[4] Blumberga, M. Risk Assessment of the Skede Landfill in Liepaja, Lativa MSc. Thesis, Stockholm: 2001

[5] Al khaldi L. Feasibility of Municipal Waste Recycling in Irbid City, MSc Thesis, Jordan, Jordan University of Science and Technology, November, 2001

[6] Abu Rukah Y., Al-Kofahi O. The assessment of the effect of landfill leachate on ground water quality. A case study. El-Akader landfill site – north Jordan. Arid Environments, Vol. 49, 2001, 615 – 630

[7] METAP, Mediterranean Environmental Technical Assistance Program (METAP). Northern Region Solid Waste Management Study. Supplementary Data Report, 1998.

[8] Chopra M., Reinhart D., El-Shaar W. US-Jordan Municipal Solid Waste Management Collaborative Research. The national Science Foundation (NSF), Final Report, 2001.

[9] Abu Qudais H. Solid Waste Management: An Evaluation and Possible Improvement for the City of Irbid, MSc thesis, Jordan University of Science and Technology, 1987.