THERMAL AND FINANCIAL EVALUATIONS OF MUNICIPAL SOLID WASTE FROM ERBIL CITY-IRAQ

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ABSTRACT

This work was aimed to study municipal solid waste (MSW) disposal problems and energy income from it. Open dumpsite and only buried of MSW causes risks to the people and the environment. Burring mixed MSW (without separation, leachate and gas collection) at Erbil Landfill Site (ELS) leads to leftover income and energy. Recyclable materials such as plastic, metals, glass, paper and cartons at ELS are income sources. Results revealed that average amount of daily disposed plastic, food waste, corrugated paper, other organics, wood, diapers, other inorganics, ferrous, and glass at ELS were 34%, 27%, 14%, 7%, 6%, 5%, 2%, 2%, 2%, and 1%, respectively. Additionally, thermal solution is required to convert the MSW and natural emitted gas from ELS to be a great source for the energy. Currently, produced methane gas and electricity from ELS are estimated to be 3,839,669.265 m^3 and 18,000.762 Kw for 1,223,834 populations, respectively. Expected annual income from recyclable materials is 97.528 $*10^6$ $. Finally, proper solution for disposed of MSW in Erbil City results in decreasing risks and environmental pollution, attainment of income by recyclable materials and release energy from gas and electricity.

Keywords: Solid waste, Methane gas, Energy, Income, Erbil City, Landfill.

1. INTRODUCTION

Communal systems for disposal and treatment of municipal solid waste (MSW) are open dumping, sanitary landfill, thermal treatment (anaerobic, pyrolysis, incineration, gasification, and plasma arc gasification) and composting. Technical landfills has been discovered to be the utmost economic MSW disposal method when equated with other systems of disposal, such as thermal and composting [1-3]. But the produced landfill leachate and gas emissions are common shortcomings of the MSW [4-5]. Without scientific solution, disposed landfill leachate and emitted gas from Erbil Landfill Site (ELS) cause pollution of the environment.

ELS regards as anaerobic landfill with daily cover-Level II [6]. In type II landfills, proper gas and leachate managements are not available [7]. Organization of emitted gas leads to decreasing environmental pollution and achieving income from the produced energy.

Increments of population numbers, growth of investment and economy, tourist, and industrialization are between the key parameters that promote the generation rate of MSW. Disposal of around 2000 tons/day of mixed MSW at ELS requires sufficient landfilling area, proper design, and management [8]. Issues on the engineering designs of landfill sites can often be detected in the developing countries, such as Iraq. Presently, more than 40 open dumpsites and landfills are available in Erbil City- Iraq. Most of the landfills consist only of dumping sites of mixed MSW without any managements to protect environment [6]. In addition, mixed disposed MSW leads to rapid finishing of landfill areas and lost huge income from daily covering the recyclable materials by soil. A study on domestic solid waste components published by [2]. The percentage of the recyclable materials plastic, metals, glass, and papers were 6.28%, 3.6%, 3.42%, 5.9%, respectively. The average amount of recyclable materials is more than 30 % in southern Asia Nations [7]. Based on the study conducted by Erbil Municipality in 2016, the percentage amount for plastic, food waste, paper, other organics, wood, diapers, other in-organics, ferrous, glass, and aluminum are 34%, 27%, 14%, 7%, 6%, 5%, 2%, 2%, 2%, and 1%, respectively [8].The disposed MSW at ELS is a massive amount which results environmental pollution and losing of affordable amount of money.

The objectives of the present work were: 1) to study the achievable income from recyclable MSW materials and 2) feasible produced energy (methane gas and electricity) from disposed MSW in Erbil City.

2. MATERIALS AND METHODS

The current work presented the ELS problems, especially mixed MSW without separation and emitted gas, and attainment of income and energy from MSW at ELS. The data were obtained from literature and Presidency of Erbil Municipality [2-6, 8-9]. To see the risks directly and to get extra information, site visit were carried out to ELS in June and November 2017. The quantity of produced methane gas and energy was based on equations and information from references [9-12]. Information and data given in the present research were obtained from published works, presidency of Erbil Municipality and administration staff for ELS and it became a scientific document for the upcoming works. The details for ELS, recyclable materials, and energy production are shown below.

2.1 ELS (ERBIL LANDFILL SITE)

ELS is located on the left side of Erbil-Mosul main road near Kani-Qrzhala Sub-district in Erbil City, Iraq. The geographical coordinates are 36°10'23" N and 43°35'32" E. It is opened in 2001 and it is approximately 15 km from Erbil City center. The total site area of ELS is 37 ha. Most part of the area has been used. In 2017, the site receives about 2000 tons of mixed MSW daily (Based on Administration Staff of ELS, 5 November 2017), Figure 1:

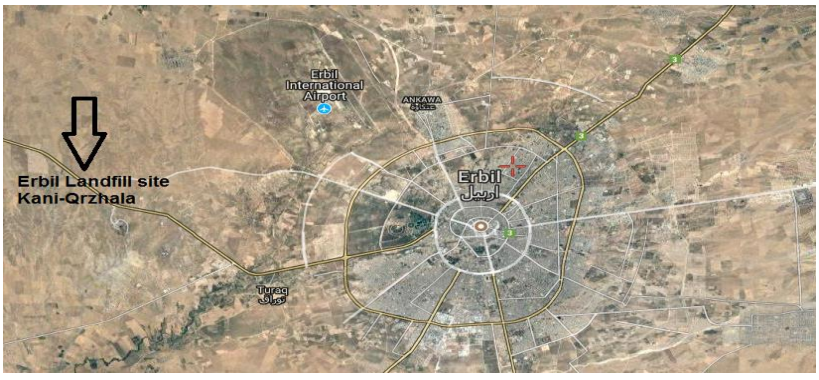

FIGURE 1. Satellite image of Erbil Landfill (Kani-Qrzhala) site.

The buried MSW is mixed without proper separation of the components. A small portion of recyclable materials, such as plastic, glass, and metals, are being separated by scavengers persons. Due to lack of scientific sanitary landfill design in this site, the formed gas is emitted to the atmosphere without any gas collection system which can be used as renewable source of energy, Figures 2 and 3.

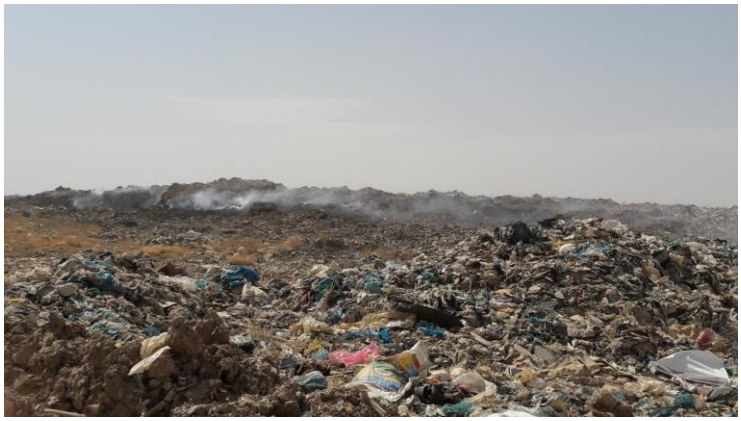

FIGURE 2. Gas emission at ELS (13 June 2017)

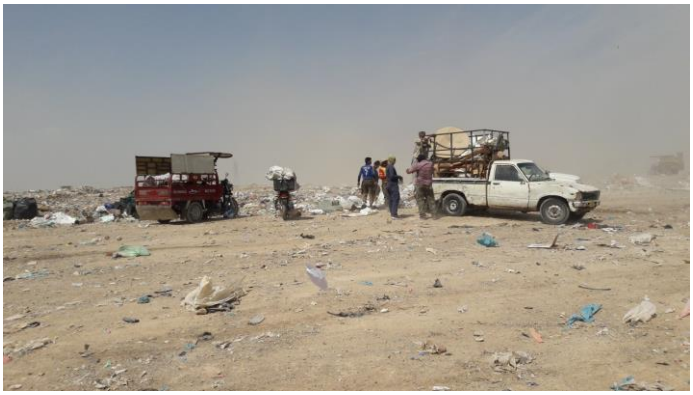

FIGURE 3. Separation and collection of recyclable MSW at ELS (13 June 2017)

2.2 RECYCLABLE MATERIALS

In this research, recyclable materials for MSW at ELS represent plastic, metals, glass, and papers [9].

2.3 ENERGY PRODUCTION

2.3.1 METHANE GAS PRODUCTION

Usually, proper landfill management required to enhance both yield and quality of gas. In order to estimate gas production, four parameters should be known which are: (a) gas yield per unit weight of waste, (b) the lag time prior to gas production, (c) the shape of the lifetime gas production curve, (d) and the duration of gas production [10].

An equation is used to determine gas production, which published by Environmental Protection Agency (EPA) and the model called Landfill Gas Emission Model (Land GEM), and the equation ranging from single value to linear increase/ linear decline, to exponential decline as follow [10]:

$$\boldsymbol{Q_T = \sum_{i=1}^{n} 2kL_{\circ} M_{ie} e^{-kti}} \qquad (\mathbf{1})$$

Where:
Q_T = total gas emission rate from a landfill, volume/time.
n = total time periods of waste placement.
k = landfill gas emission constant, time $^{-1}$.
L_o= methane generation potential, volume/mass of waste.
t_i = age of the i^{th} section of waste, time.
M_i = mass of wet waste, placed at time i.

Erbil landfill opened in 2001 year, and it receiving 2000 tons/day, which means 730,000 tons/year. Assume landfill emission gas constant is (0.0307 year^{-1}), and the methane generation potential is (140 m^3/tons), to estimate peak gas production:

For the first year of opening in (2001):

Q_T= 2(0.0307)*(140)*(730,000)*(e $^{-0.0307(1)}$)
Q_T=6,085,362.114 m^3

For age at ti =15 (in 2016)
Q_T= 2(0.0307)*(140)*(730,000)*(e $^{-0.0307(15)}$)
Q_T=3,959,375.196m^3
For age ti =16 (in 2017)
Q_T= 2(0.0307)*(140)*(730,000)*(e $^{-0.0307(16)}$)
Q_T=3,839,669.265 m^3

2.3.2 POWER GENERATION

The generation rate (GR) of disposed garbage, plastic, paper and fabric = 608.02 g/cap/d (excluding glass and metals) [2, 9].

608.02 g/cap/d = 1.34 Ib/cap/d

Energy available in each 10^5 population [9, 11-12].

= 1.34 * 10^5*4500/24

= 2.51 * 10^7 BTU/h

Where BTU is British thermal unit

But, the efficiency is 20% and the theoretical value of the mechanical equivalent of heat is 3413 BTU/h. Therefore the heat rate is:

3413 / 0.2 = 17065 BTU / KWh

$$\text{Energy generated (KW)} = \frac{\text{Heat available in fuel}}{\text{heat rate}}$$

= 2.51 * 10^7 / 17065
= 1470.85 KW for each 10^5 population
For population of 1,223, 834 [8]:
Energy generated (KW) = 18000. 762 for 1,223, 834 populations

For MSW at ELS, GR= 1270 g /cap/d =2.803 Ib/cap/d [8].
Energy available in each 10^5 population
= 2.803 * 10^5*4500/24
= 5.256 * 10^7 BTU/h
Disposed MSW at ELS produces from 1,223, 834 [8]:
Energy available for 1,223, 834 populations = 6.432 * 10^8 BTU/h

3. RESULTS AND DISCUSSIONS

3.1 CURRENT SITUATION OF ELS

ELS considered as Level 2, which is sanitary landfill with daily cover, and anaerobic landfill, it also in the methane formation phase [6]. Based on the landfill structures shown in literature, upgrading the site from Level 2 to Level 3 Level 4 is essential [2]. Disposal of mixed MSW at ELS leads to terminate the provided areas for Landfilling. A part of recyclable materials is separated by scavengers only, Figures 3-4. Providing suitable system for separation of recyclable materials is recommended. In addition, a mixed-waste materials recovery facility (MRF) technology is recommended [9]. On the other hand, formed landfill leachate still discharges to the natural environment without treatment [3-4, 13].

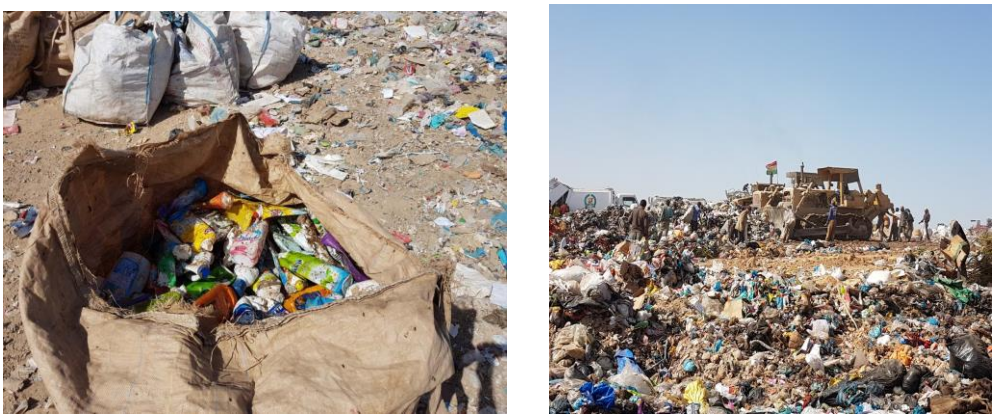

FIGURE 4. Collected recyclable materials by scavengers at ELS (5 November 2017)

3.2 INCOME FROM RECYCLABLE MATERIALS

Recycling is an important subject in life, especially when it used final disposal products and again reused [14]. The recycling targets of the global waste management system, therefore focusing on the complete waste collection in future, and the achievement of waste management in study area. Therefore the necessary recycling facility required, but the waste still not separately collected. The aim of MSW recycling programs should not be to increase MSW recycling [15]. The objective should be to upgrade environmental quality and the sustainability of the economy, and from construction and demolition materials.

Recycling of MSW materials lead to achieving income, decreasing amount of MSW in landfills, minimizing environmental pollution, decreasing number of MSW collector

truck and crew size, decreasing scavengers problems in the landfill site, injury, increasing area for landfilling, and upgrading control/management of the landfill site.
Table 1 illustrates the details for calculation of income from the recyclable materials in Erbil City. The recyclable materials were plastic, ferrous, aluminum, glass and paper. The recoverable of recyclable materials are different [16]. Due to lack of scientific documents for the recoverable materials, Average recoverability of 80 % was proposed for the present work. Annual expected income for the recyclable materials in Erbil City is 97.528 * 10^6 $/year.

TABLE 1.
Details of income from recyclable materials

Recyclable Material	Ratio (%)	Amount * (tons/day)	Assumed average Price ($/tons)**	Average recoverable materials (tons/day)**	Income ($/day)	Income (10^6 $/year)
Plastic	34	680	400	544	217600	79.424
Ferrous	2	40	200	32	6400	2.336
Aluminum	1	20	1500	16	24000	8.76
Glass	2	40	75	32	2400	0.876
Paper	7	140	150	112	16800	6.132
Total	46	920		736	267200	97.528

*Total daily MSW disposal = 2000 tons/day
**Source: [16]

3.3 METHANE GAS AND ENERGY PRODUCTION

Depending on the equation, it is clear that for the second year, the waste produces les gas, but the next new layer produces more gases, and the two are added to yield the total gas production for the second year. The emitted methane gas from landfill site can be used to produce electricity, heat, and fuels by decomposing garbage, Figures 2 and 5.
The emitted gas can be directly used in boiler, furnaces, or kilns in the treatment system. Since ELS gas emissions are a global problem, so that, it must direct attention to improve these problems. If this can be provided, so it can be a major source of energy for the study area.
On the other hand, the study presented the assessment of environmental impact of ELS, and proposed applying processed waste to provide income and power generation especially in a manufacturing process where heat is required.

By using refused derived fuel (RDF) for the purpose of achieving high calorific fractions from processed (MSW) and industrial wastes or any other wastes are alternative to convert (waste to energy) plants.

RDF production appear most common way to achieve relatively high levels of recycling and composting ELS as high rates of source separation leave non-recyclable residues, which are suitable for RDF production.

Even in cities where the source of separation is not so well-developed, and where the source of separation with or without residual waste processed, it might be sufficient to get the landfill directive target, especially in waste management system will be very important.

In the present work, the expected total gas emission rate (Q_T) form ELS in 2017 is 3,839,669.265 m^3 which is huge amount and need proper management. Estimated electric energy generation is 18,000.762 KW for 1,223, 834 populations. Authority has problem for supplying 24 hours electricity for Erbil population due to loses and bad using of electricity, increasing population number etc. Finding another source for supplying electric with 18,000.762 KW from disposed MSW to Erbil City is very important and leads to environmental pollution. Furthermore, predictable energy available for 1,223, 834 populations in Erbil City is $6.432 * 10^8$ BTU/h. Nowadays, achieving this quantity of energy to Erbil City from discarded MSW is so valuable and results in decreasing pollution in the city.

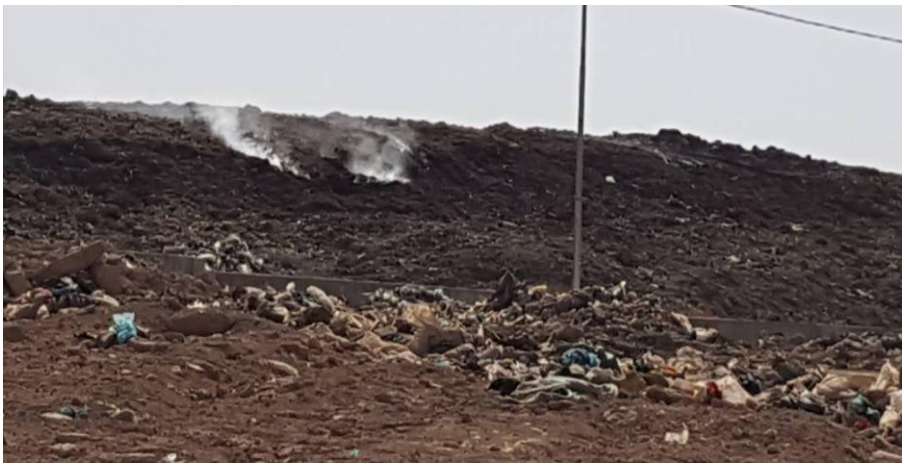

FIGURE 5. Gas emission from ELS (5 November 2017)

4. CONCLUSIONS

In this study, it was observed that there is a lack from MSW management as ELS. Gas emission, leachate production, burring and inadequate of recyclable materials, and non-acceptable view are main characteristics of ELS. A number of buildings and facilities such as offices for administration, laboratory, guard house, weighing station, storerooms, fence, gas collection, leachate collection and treatment unit, and wells for groundwater monitoring are essential for ELS. Upgrading ELS from Level 2 to level 4 by proper management for emitted gas and produced landfill leachate is recommended. Providing suitable system for separation of recyclable materials is suggested as well. Expected annual income from recyclable materials is 97.528 $*10^6$ $. Foreseeable quantity of methane gas at ELS in 2017 is 3,839,669.265 m^3. Predictable amount of energy and electric from MSW at ELS are 6.432 * 10^8 BTU/ h and 18,000.762 KW, respectively.

Form ELS the measured methane gas from obtained data have the wide variability over space, in some cases, the land fill has been shown to act as net sinks for atmospheric methane, it should be incorporate to measure the influence of the produced gas and controlling it by the presence of gas recovery wells. At different locations at ELS huge amount of gas emitted to the environment, Figure 2. In July and August 2017, 18 gas collection pipes were penetrated to the landfill site ground. Distances between pipes are around 80 m and surrounded by filter materials.

For the entire ELS, a dis-acceptable view is seen. Administration building, laboratory, drivers and labors building, guard house, garage, fence, green area, sanitary system, weighing station etc. are essential for ELS.
The classification of solid waste form ELS revealed that most of the wastes are consists of plastic, food waste, corrugated paper, by percentages of 34%, 27%, 14%, respectively.

The ratios refer to that if the waste managed properly, it can provide a very large income and energy as well. The amount of recyclable materials from domestic wastes is 20.66%. Due to life style and economic factors in Erbil most parts of the domestic waste is food and organic wastes which was 79.34%.

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