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Comparison of a Traditional Landfill and a Mechanically-Biologically Treated waste Landfill (Case study; Kirkuk landfill)

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ABSTRACT

Owing to the increasing population in Kirkuk, Iraq and the consequent rise in the production of waste, alongside with global warming caused by an increase in the greenhouse gases concentrations, a high level of emissions was observed at the landfill site near Kirkuk. These emissions can be transmitted by the wind over considerable distances and adversely affect the environment and individual health. In this study, two pilot scale columns were built to investigate different options for achieving sustainability by reducing long-term landfill emissions. Each reactor was packed with (8.5) kg of shredded synthetic solid waste (less than 5 cm) that was prepared according to an average composition of domestic solid waste in the city of Kirkuk. The main result of this study was that the pretreatment of the waste may shorten the transition time for active methane development and increase the methanogenesis of the landfill site and also affects COD removals efficiencies which were 19.11% and 66.53% for columns A and B respectively.

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مقارنة بين مطمر نفايات تقليدي و مطمر نفايات معالج ميكانيكيا وبيولوجيا (دراسة حالة ، مطمر مدينة كركوك)

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جذوة عبد الكريم ابراهيم الامين / جامعة بغداد، كلية الهندسة ، قسم الهندسة البيئية ، بغداد ، العراق

بسبب الزيادة السكانية في كركوك بالعراق وما أعقب ذلك من ارتفاع في إنتاج النفايات ، إلى جانب الاحتباس الحراري الناجم عن زيادة تركيزات غازات الاحتباس الحراري ، لوحظ ارتفاع مستوى الانبعاثات في موقع المطمر بالقرب من كركوك. يمكن أن تنتقل هذه الانبعاثات عن طريق الرياح لمسافات طويلة وتؤثر سلبًا على البيئة وصحة الفرد. في هذه الدراسة ، تم بناء عمودين على نطاق تجريبي لاستكشاف الخيارات المختلفة لتحقيق الاستدامة من خلال تقليل انبعاثات مدافن النفايات على المدى الطويل. تم تعبئة كل مفاعل بـ (8.5) كغم من النفايات الصلبة الاصطناعية الممزقة (اقل من 5 سم) والتي تم تحضير ها حسب متوسط تركيب النفايات الصلبة المنزلية في مدينة كركوك. كانت النتيجة الرئيسية لهذه الدراسة أن المعالجة المسبقة للنفايات قد تقصر من وقت الانتقال لتطوير الميثان النشط وتزيد من توليد الميثان في موقع دفن النفايات وتؤثر أيضًا على كفاءة إزالة COD التي كانت 19.11٪ و 66.53٪ للعمودين A و B على التوالي.

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1. INTRODUCTION

Landfilling is the dominant method of solid waste disposal. The anaerobic degradation of waste in landfills by microorganisms under favorable conditions results in the emission of landfill gases (LFGs). CH_4 and CO_2 are the major fractions of landfill gases and are the primary contributors to the greenhouse gas (GHG) effect [1].According to the Kyoto protocol, there are six greenhouse gases that are listed as harmful [i.e., carbon dioxide, nitrous oxide (N_2O), hydro fluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and methane (CH_4) [2]. Developing countries generated 29% of GHGs in the year 2000. This quantity is expected to increase to 64% and 76% by 2030 and 2050, respectively [3]. In 2006, the United States contribution to methane release from MSW landfill sites was 23% of the total anthropogenic release. In addition, landfill sites are the second major sources of anthropogenic (GHGs) in the United States. It is expected that 3.8% of the global warming potential (GWP) in the united states of America (USA) is correlated to methane (CH_4) releases from landfill sites [4].

The city of Kirkuk is the center of the Kirkuk Governorate. The Kirkuk Governorate is located 238 kilometers to the north of Baghdad (longitude 35.46667º north and latitude 44.31667º east). It is one of the richest oil provinces [5].

The area of the city is approximately 5023 km^2. The city is located 350 m above the sea level; the city experiences a semiarid climate with hot, dry summers and cool rainy winters; the mean annual temperature is 28.7°C, the annual humidity is approximately 48.5%, and an average annual rainfall is approximately 361.3 mm [6].

The landfill near Kirkuk is the first environmentally designed and constructed landfill in Iraq since 2008. The design and construction of Kirkuk's only landfill complies with the US Environmental Protection Agency (US EPA) guidelines for the Class 1 sanitary landfill site and with the European Union Landfill Directive standards. The landfill site is located in Zindanah village of the Kirkuk Governorate, 18 km to the south of Kirkuk between Taza and Leylan [7]

The Kirkuk sanitary landfill started working in February 2008. It has a predicted life span of 30 years. It accepts waste from domestic and commercial sources, rubber tires, and consumable goods; the landfill has a designed waste capacity of 4.2×10^6 m^3 [8]. Two transfer stations located 17 km and 35 km to the south and to the north of Kirkuk, respectively, were installed for saving time and making waste collection and transportation more flexible. Large metal pieces are the only type of waste that is sought by scavengers for potential recycling. The Kirkuk sanitary landfill was provided with a liner system composed of a 0.6-m thick clay layer with a hydraulic conductivity of 1×10^{-7} cm/s and a 1.5-mm thick high density polyethylene (HDPE) geo-membrane liner [7]. The leachate collection and treatment system is comprised of a 0.52-m gravel drainage layer, a series of 12 perforated PE leachate extraction pipelines with a non-woven geo textile wrap (gravity drained), and chemical dosing and aerobic digestion units [8]. Because there is no gas collection or treatment system attached to the landfill, gases are emitted into the ambient surrounding air. Thus, the objectives of this research are to investigate different options for achieving sustainability by reducing long-term landfill harmful emissions (gas and leachate).

1.1The importance of mechanical biological pretreatment

Pretreatment of waste prior to landfill supports sustainable landfilling by controlling or minimizing landfill emissions. Additionally, the aftercare requirements can be significantly reduced. Pretreatment includes mechanical and biological processes[9]. Mechanical process includes shredding, screening, sorting, and separation of ferrous items. The resulting volume reduction and increase in the specific area of the waste can be attained, thereby increasing its specific density. As a result, biological performance of the succeeding biological pretreatment step is enhanced and stabilized [10]. Biological

pre-treatment process involves degradation process that converts organic portion into useful end products potential for resource recovery. Finally, the overall strategy promotes least hazardous chemicals introduced into landfill [11].

1.2Waste Composition of the Kirkuk Governorate

The main waste stream in the Kirkuk governorate is the municipal solid waste (MSW), which includes residential, commercial, institutional, industrial, and public (street cleaning) waste. Solid waste was introduced in the bioreactors, representing common locally solid waste composition of Kirkuk, as shown in **Table.1.**

Table 1

Waste composition weight percent

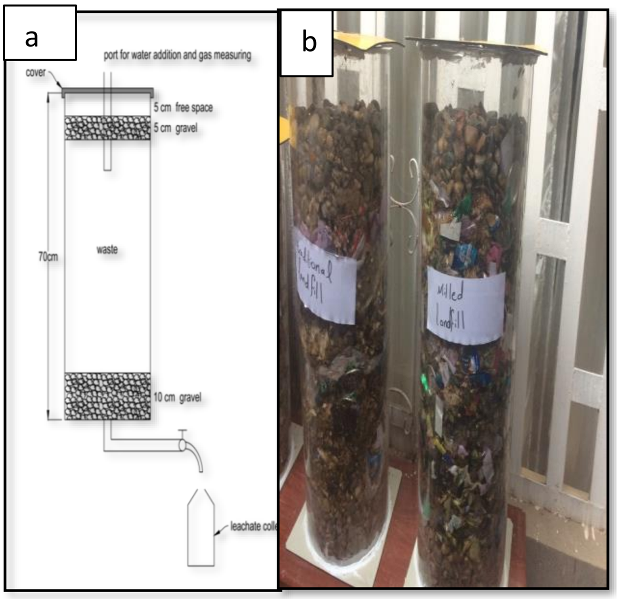
Component	Percent%
Food waste	60-62
Plastic	8-10
Metal	5-6
Paper/cardboard	6-8
Textiles	6-7
Rubber	3-4
Glass	3-4
Other	8-10

2. EXPERIMENTAL WORK

2.1 Reactor Configuration

Two laboratory-scale Plexiglas reactors were built and maintained at a steady mesophilic temperature of 35°C to keep a good environment for the growth of microorganisms in both reactors in the summer. Each reactor had an internal diameter of 300 mm and an effective height of 700 mm, as shown in Fig.1.

Each column was equipped with two ports: one for drainage and sampling, and the other one for gas sample



collection and liquid addition. The leachate was stored in plastic bottles for recirculation purposes. Biogas from columns (A) and (B) were collected in gas plastic bags and the collected gas was measured every week.

2.2 Reactor Loading

Eight and a half kilograms of fine milled (shredded), sieved on5cm cm and hardly compacted solid waste was introduced in the column (A), representing common locally solid waste composition of Kirkuk.

Column (B) was filled with 8.5 kilo-grams of mechanical-biological pretreatment (MBP).MBP waste was also milled and sieved as well as subjected to 5 weeks of natural aeration prior filling into column (B) [12].

2.3 Reactor Landfill Operation

Column (B) was operated to evaluate the impact of mechanical biological treatment on solid waste decomposition, while (A) column presented a common sanitary landfill environment. The preliminary analysis of waste specimens indicated that solid waste contained approximately 65% of moisture; thus, tap water was provided to each reactor to achieve the field capacity. Throughout the study period, once a week, 1 L of leachate that had been collected from both reactors in storage bottles was recycled. Reactors were fed with distilled water to simulate precipitation. The amount of water was calculated based on the liquid to solid ratio (L/S=6.5).

3. RESULTS AND CONCLUSIONS

3.1 Leachate phase

3.1.1 pH

The results of the pH values for all columns are shown in Fig. 1. pH values of leachate samples of traditional column (A) were less than 5.5 for almost the entire study period, reflecting the accumulation of fermented acids (acidogenesis phase). For mechanical biological waste column (B), pH values increased a little bit, but readings were all less than 7 till the end of experiment's time. It can be concluded that methanogenesis phase has not begun and stabilization has not occurred in (A) column.

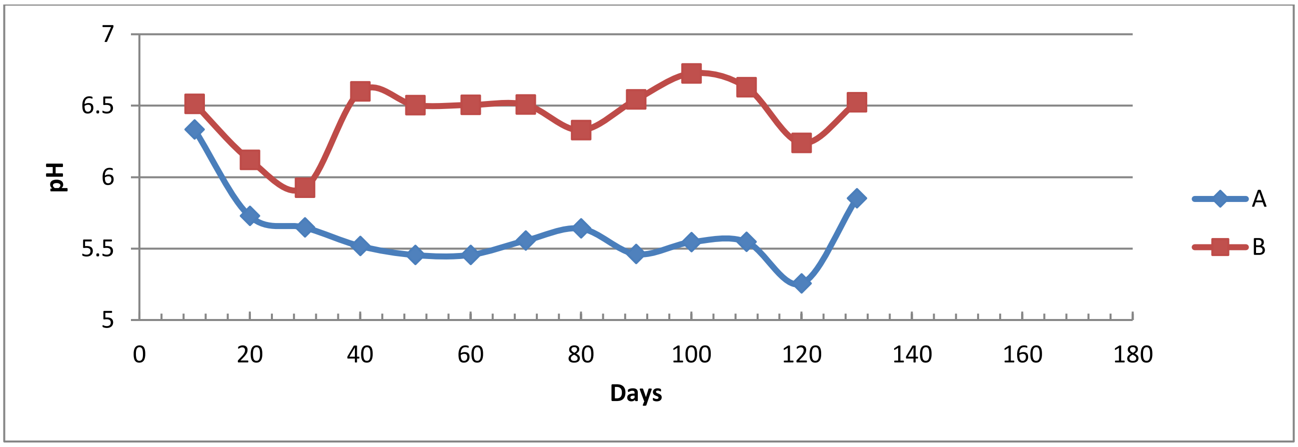


Fig.2 pH reading for both columns

3.1.2 COD

The concentrations of COD in sequent leachate's samples collected from both columns each week were graphed in Fig. 3.COD readings for both columns, increased slightly within the first 20 days. Starting from (51,132) and (25,493) mg/l reaching (57,014) and (25,987) mg/l, respectively.

As time passed, oxygen began to deplete in the anaerobic columns and finally was exhausted, where microorganism began to dominate, taking advantage of circumstances of anaerobic conditions; most complex organic compounds were degraded into smaller molecules, which can be dissolved in leachate, leading to a high COD concentration values [13]. At the end of the study the values of COD were (13789 and 9860.4) for (A and B) columns, respectively.

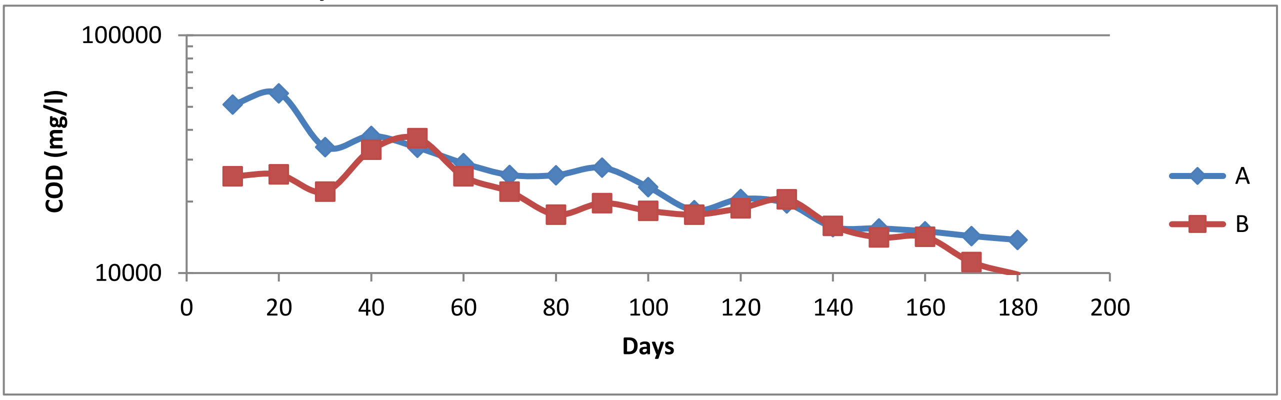


Fig. 3 COD readings for both columns

3.2 Biogas Phase

***3.2.1Conventional Column (A)*:** In (A) column, exhibited a delay of methane generation, because the acidogenesis period lasted a long time, verified by a high concentration of COD and low values of pH in the column. Methane rate of production was slow and the production maximum rate could not be detected during the first 137 days of the study. **Kylefors et al.** (14) stated that longer time is to be taken to run through initial stages of adaptation, transformation and acid deposition before reaching the methane development period because the processes of anaerobic degradation were not maximized at the landfill, while for CO_2 gas ,it kept on increasing then begun to slow down due to carbon depletion in organic material in the waste. Trends were exhibited in Fig. 4.

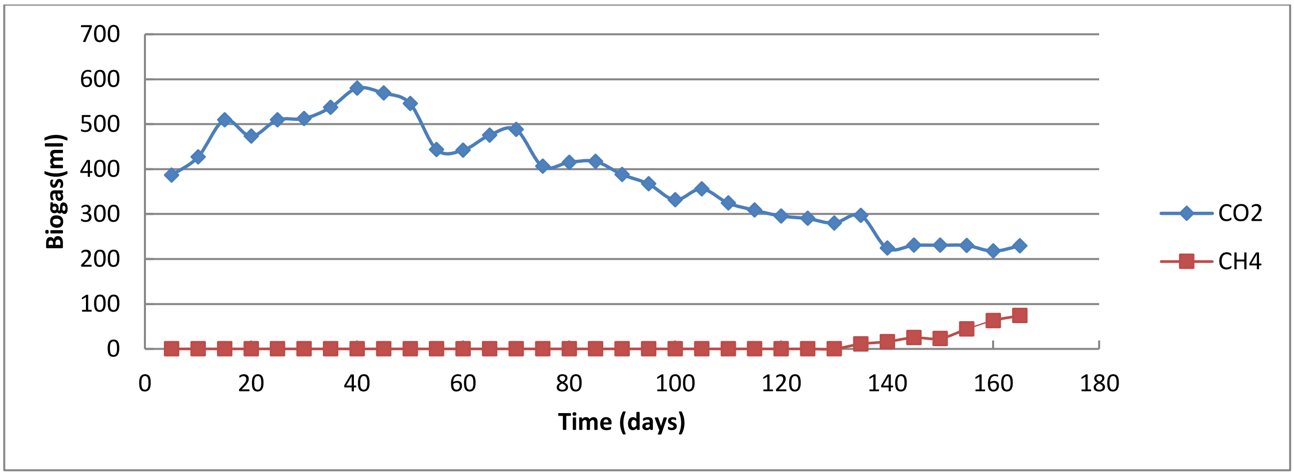
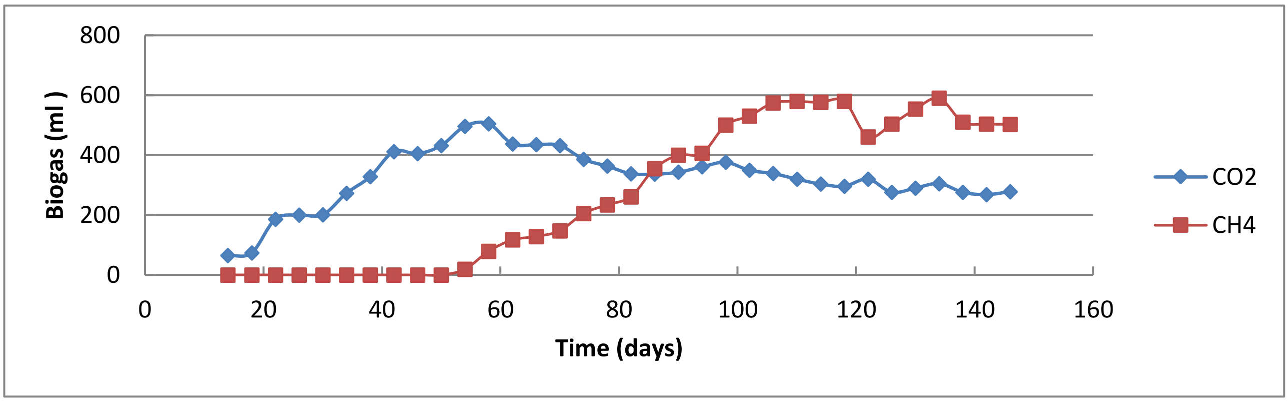


Fig.4 Biogas vs time for column (A)

***3.2.2 Column (B)*:** It seems to accelerate the methanogenic phase, with a very short period of acid phase with pH of leachate = 6-6.5. Results come up with evidence that the pretreatment of the waste might shorten the transition time for active methane development and increase the methanogenesis of the landfill site. MBP column, maximum production of gas was observed 56 days after the start of anaerobic digestion. It was also observed that by increasing the ratio of L/S, this leads to an increase in humidity and also to a decrease in acidity, so the production of methane increases.CO_2 gas kept in accordance with CH_4 but with different peak s time as shown in Fig. 5



This suggests that particular caution should be paid when using the results of lab-scale tests for the evaluation of long-term behavior expected in the field where the boundary conditions change continuously and vary significantly depending on the climate, the landfill operative management strategies in place (e.g. leachate recirculation, waste disposal methods), the hydraulic characteristics of disposed waste, the presence and type of top and final cover.

4. CONCLUSION

1. Column (B) has a higher pH than column (A) and maintained at a pH mostly greater than 6.
2. Conventional anaerobic landfills show a higher level of release, with high concentrations of (COD=15432mg/l).
3. The pretreatment of the waste may shorten the transition time for active methane development and increase the methanogenesis of the landfill site.
4. Faster methane generation in column B means that waste reaches sustainability sooner leading to reduced emissions for the long term.

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