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Comparison of Conventional and Aerobic Landfill Simulator Reactors (case study; Kirkuk city, Iraq)

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Abstract:

Under aerobic and anaerobic conditions, two laboratory-scale reactors were operated. 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. Using an air compressor, aerobic conditions were created in the aerobic reactor. This study shows that the aerobic reactor was more efficient in COD and BOD5 removal which were 97.88% and 91.25% while in case of anaerobic reactor, they were 66.53% and 19.11%, respectively.

Keywords: Aerobic landfill, Anaerobic, Laboratory scale, Kirkuk landfill, Kirkuk.

Introduction:

The city of Kirkuk, like most metropolitan cities, experiences considerable problems associated with the management of municipal solid waste (MSW). According to the Mineral Resources Data System, approximately 0.8 kg of waste is produced by one person per day in Kirkuk. The amount of solid waste was expected to increase from 840,000 tons in 2008 to 1,156,445 tons in 2020 due to the large population expansion in Kirkuk (1). Increasing population density has resulted in the rise in the quantity and quality of waste, which creates a considerable risk to national health due to the absence of appropriate solid waste management system (2). Increasing attention is paid to recirculate of leachate in municipal solid waste landfills as an efficient approach to increase the microbial break down of putrescible fractions of solid waste(3). Utilizing leachate recirculation, a landfill can be used as an anaerobic filter to handle the leachate, accelerate waste stability, and decrease the amount of leachate by maximizing evaporative losses during the process of recirculation (4). Several studies have shown that waste decomposition can be enhanced by an increase in the water flow owing to the enhanced flushing and dilution of inhibitory materials. This process maintains a favorable environment through the consistent moisture

distribution and addition of higher quantities of inoculums and nutrients (3,5,6).

Traditional techniques of bioreactor landfill operation strive to stabilize anaerobic waste(7). Recently, there has been an increased interest in the addition of air into the landfill mass for aerobic solid waste decomposition(4). Aerobic bioreactors have been adopted to accelerate waste stability. Previous studies on aerobic decomposition procedures have shown that the putrescible components of the waste can be decomposed faster under aerobic conditions than under anaerobic decomposition. The concept of aerobic decomposition by the injection of air into the body of landfill offers considerable benefits in waste management both for existing and new systems (8).

The main aim of the present study is to explore the impact of leachate recirculation and aeration compared with various other alternatives that are available for sanitary landfilling and to provide information for the effective operation of the Kirkuk sanitary landfill.

Materials and Methods:

Experimental design and reactor configurations

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.

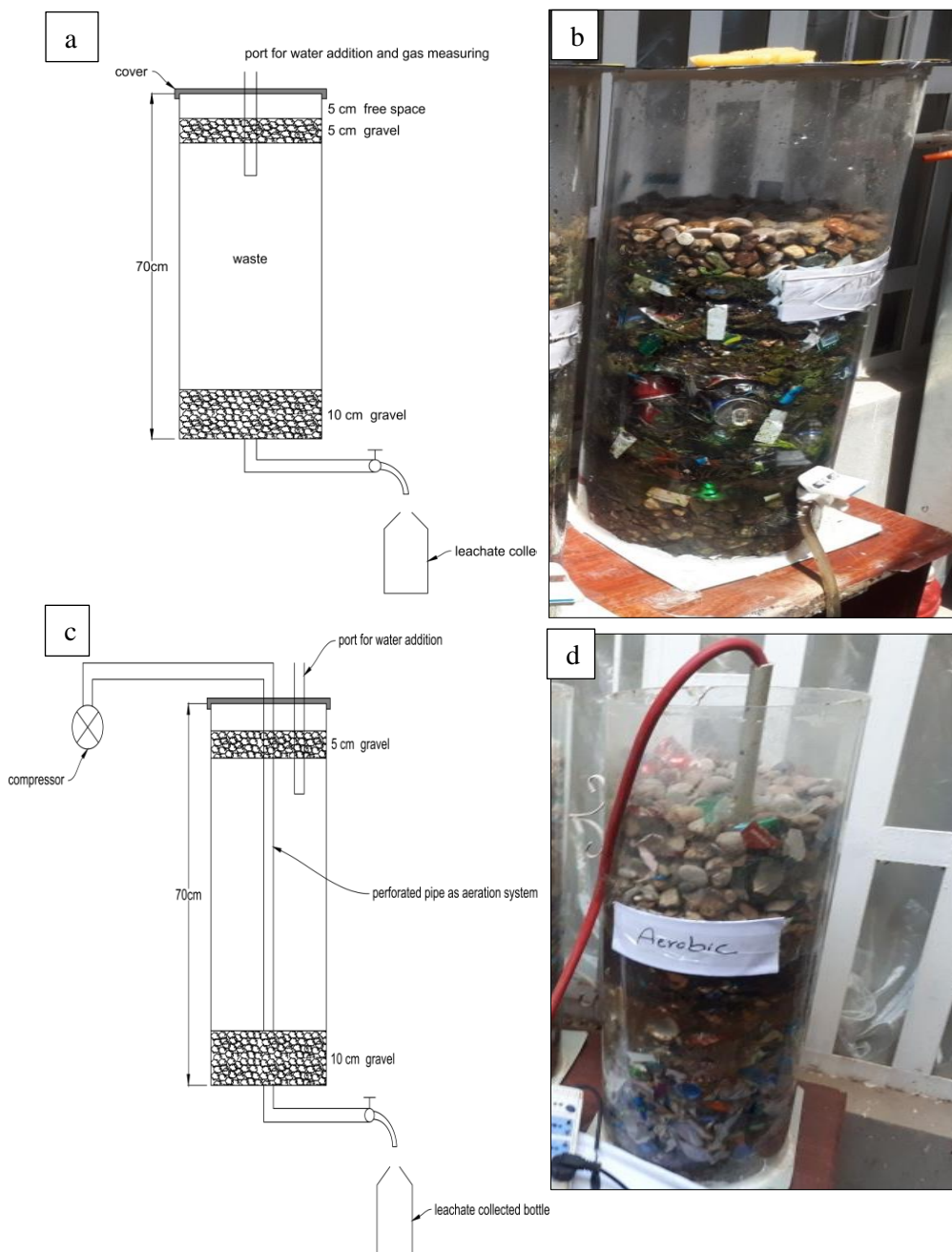


Figure 1. (a) Schematic diagram of an anaerobic reactor and (b) its picture; (c) schematic diagram of Aerobic reactor and (d) its picture

Each reactor 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. Aerobic conditions in the reactor were conducted utilizing an air compressor. Leachate recirculation was utilized to supply a transport mechanism for microbes and to achieve

product stabilization for further conversion. pH monitoring for leachate quality was performed using a portable pH meter (Hanna, India), while total dissolved solids and electrical conductivity were analyzed using a YL-TDS2 meter (India)

Reactor loading

Eight and a half kilograms of fine milled (shredded) and hardly compacted 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 (9)

| Component | Wt% |
|-----------------------------------|------|
| Organic (food + garden trimmings) | 70 |
| Plastic | 5 |
| Glass | 3.54 |
| Paper | 4 |
| Metal | 8.4 |
| Textile | 2 |
| Others | 8 |

Reactor landfill operation

Reactor (A) was operated aerobically to evaluate the impact of aeration on solid waste decomposition, while the anaerobic(B) bioreactor 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). The air compressor was connected to the aerobic reactor through an air inlet at the tank bottom with a flow rate of 2.2 L/min for 6 h per day for 5 days to sustain the stable aerobic environment.

Results

Leachate quality

pH

Initially, the values of pH of both aerobic (A) and anaerobic (B) reactors were 6.2 and 5.8, as shown in Fig.2. However, in the aerobic(A) reactor, the acidic pH was changed to neutral within 10 days and reached a value of 6.8. After eighty days, the pH value was 7.3. Thereafter, no considerable changes in pH were observed for the aerobic reactor. However, the value of the pH of the anaerobic reactor was 5.7 at the end of the study. These results have confirmed that the degradation of solid waste under aerobic conditions was faster compared to that under anaerobic conditions. The results of this study are supported by those of Cossu et al. (8), Bilgili et al. (10), and Ko et al. (5).

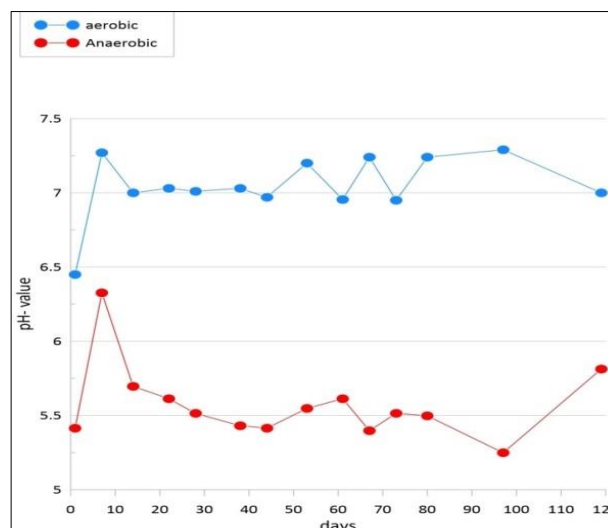


Figure 2. pH values for both reactors

Total dissolved solids

The total dissolved solids (TDS) parameter was monitored to assess dilution and washing impacts. TDS values of aerobic (A) and anaerobic(B) reactors showed a similar declining trend, which may be observed due to the same volume of rainwater and the same ratio of leachate recirculation were introduced for both reactors. A decline in the dissolved solids concentrations was observed because of the water dilution effect in the rainfall simulation. The initial dissolved solids values were 2244 mg/L and 1912 mg/L for the aerobic(A) and anaerobic (B) reactors, respectively. At the end of the study, these values decreased to 1287 mg/L and 546 mg/L, respectively. Kylifors et al. (11) reported that the total solids (TDS) concentration is expected to decrease as the leachate transitions from acidogenic to methanogenic phase. Slezak et al. (6) reported the same results for the TDS but indicated that the concentrations of dissolved solids do not significantly show any changing compared to those of total solids.

Electric conductivity (EC)

Leachate's conductivity represents its total ionic solute concentration and is a measure of the capacity of the solution to transmit an electrical current. In both reactors, a similar trend was observed for the change in the leachate conductivity with time. Along with decomposition, the conductivity values started with (1640 mS/cm) in the aerobic(A) and (>1644 mS/cm) in the anaerobic (B) reactor raised to the maximum values of 1931 and 2763 MS/cm, respectively, and then slowly declined to 848 MS/cm and 1098 MS/cm throughout the experiment, as shown in Fig.3.

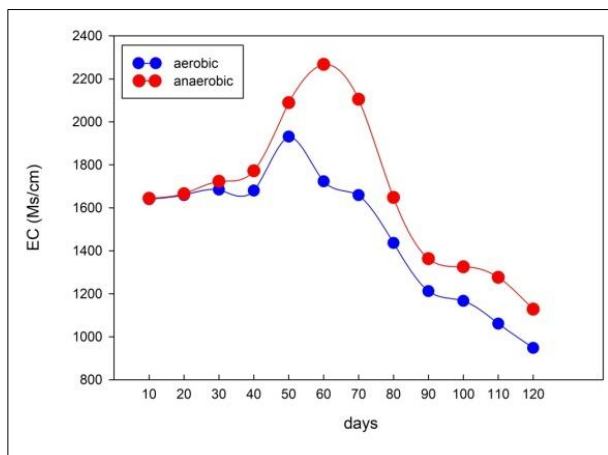


Figure 3. Conductivity values of both reactors as a function of time.

This decline may be attributed to the fall down and water washing that washed the running of ions such as heavy metals, Cl, and SO₄ ions. For the aerobic (A) reactor, theoretical conductivity dilution substantially compatible with the experimental observations. For the anaerobic(B) reactor, the theoretical electric conductivity dilution gradient was lower than the experimentally observed value. This is attributed to the mobilization of ions under acidogenic conditions, which was not considered in theoretical calculations.

COD & BOD₅

Chemical oxygen demand (COD) is the measurement of all chemicals (organic and inorganic). The concentration of COD in aerobic(A) and anaerobic(B) reactors were 45780 mg/L and 28585 mg/L, respectively, as shown in Fig.4. Then, in the aerobic(A) reactor, the COD concentration raised to 34800 mg/L and then quickly decreased until it finally reached a value of 2567 mg/L.

The COD concentration in the anaerobic (B) reactor raised to 57000 mg/L due to the release and hydrolysis process of complex organic materials of solid waste. COD remained at the same high concentrations owing to the accumulation of organic acids and reached to (15432)mg/L. These results are comparable to the results of Cossu et al. (8) who showed that high concentrations of COD (20000 mg/L) were observed in the anaerobic reactor compared to that in the aerobic reactor (800 mg/L) after 120 days of experimental study.

BOD₅ is a measure of how much oxygen the bacteria needs to degrade organic components in the leachate. a BOD₅ between the two reactors presented a similar behaviour to COD. The initial BOD₅ concentration in aerobic (A) was 4012.22 mg/ L and reduced ultimately to 85.42 mg/ L, with a reduction of 97.88%. In anaerobic(B), the

initial BOD₅ values was reduced from 12758mg/L to 10347mg/ L, with a 19.11% reduction(Fig.5).

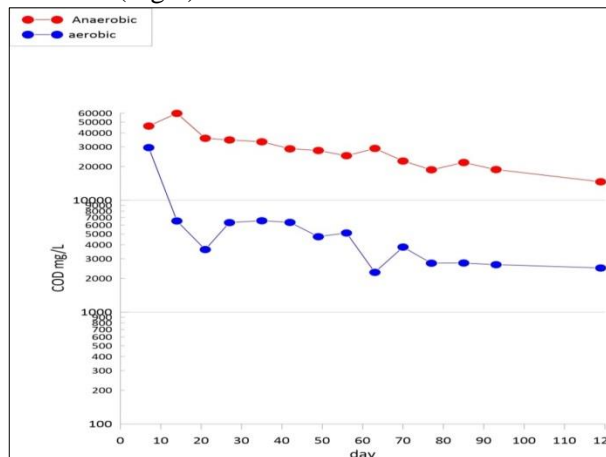


Figure 4. COD concentration for both reactors

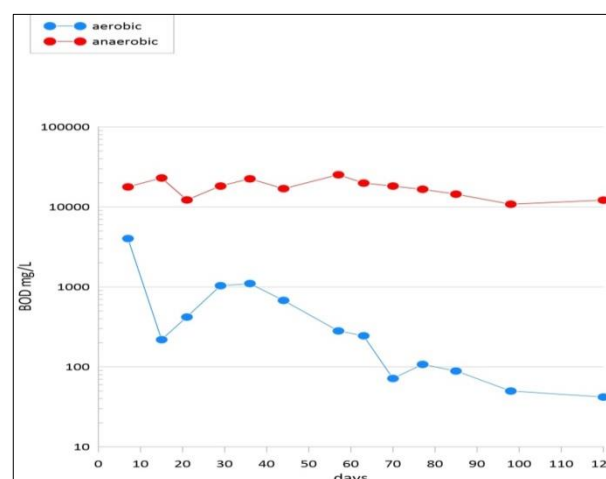


Figure 5. BOD₅ concentrations for both reactors

Impact of aeration on landfill settlement

The stabilization of landfills is defined by the settlement and reduction ratio(12). The settling results from long-term organic biodegradation are described in Fig.6 . During the study, the settlement of waste was monitored and calculated by equation 1:

$$Settlement \% = \frac{h_i - h_f}{h_i} \times 100 \quad [1]$$

Where h_i = the hight of solid mass inside column at the first day of experiment (cm).

h_f =the height of solid waste mass inside column at the end of experiment (cm)

$$Settlement \% = \frac{50 \text{ cm} - h_f}{50 \text{ cm}} \times 100$$

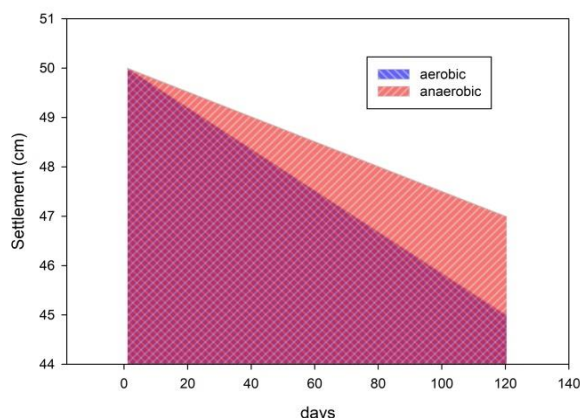


Figure 6. Settlement of the waste during the study

The settlement of aerobic (A) and anaerobic (B) on the last day of the experiment (i.e., 120 days) was 5.4% and 2.64%, respectively. The result showed that the settlement degree of (A) was almost double compared with that of (B). This observation indicates that the settlement of waste increased by introducing air into the landfill mass.

Conclusion:

1. Low levels of all measured parameters (COD=2567mg/L and BOD=85 mg/L) were observed in aerobic bioreactors compared with those in anaerobic bioreactors.
2. Aerobic bioreactors are maintained at a neutral pH with 7.3.
3. Conventional anaerobic landfills show the highest level of release, with high concentrations of (COD=15432mg/L and BOD₅=10347mg/L).

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Baghdad.

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مقارنة مفاعل محاكاة مكب النفايات التقليدي والهوائي (دراسة حالة، مدينة كركوك)

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الخلاصة:

تم اجراء هذه الدراسة بتشغيل مفاعلين على نطاق المختبر أحدهما في ظل الظروف الهوائية والآخر في ظل الظروف اللاهوائية. تمت تعبئة المفاعلات بـ 8.5 كيلو جرام من النفايات الصلبة الاصطناعية المقطعة (أقل من 5 سم) المحضرة وفقاً لمتوسط تركيبات النفايات الصلبة المحلية المحددة في مدينة كركوك. تم إجراء الحالة الهوائية في المفاعل باستخدام ضاغط الهواء. أشارت نتائج التجارب إلى أن المفاعل الهوائي له كفاءة أعلى من المفاعل اللاهوائي في خفض COD, BOD.

الكلمات المفتاحية: المكب الهوائي، اللاهوائي، مقياس المختبر، مكب كركوك، النفايات الصلبة البلدية.