Organic Component and Nitrogen Removal of Fresh Waste Leachate by Circulating on Old Waste Deposits as a Pretreatment

Mohssen Shoeybi and Jonathan L. Salvacion

Abstract—**Traditional waste management in landfills made the leachate a serious environmental problem. Effective treatment for landfill leachate because of high concentration of organic and nitrogen components is of great importance to reduce its adverse impacts on environment. Applicability of leachate pretreatment based on recycling the leachate of fresh waste on old waste was investigated in this study. In first step an LSR with 200L volume filled with fresh waste and had run until its parameters showed degradation for more than 90%. In second step two different landfill simulation reactor (LSR) systems were setup, each set-up consist of two LSRs in series. In the first set-up, both reactors filled with fresh waste and their leachate was recirculated daily by peristaltic pump at constant rate. In the second set-up daily the leachate from fresh waste LSR (A2) was passed through the second LSR (B2) which filled with old waste that prepared in previous step, while at the same time the leachate from reactor B2 was passed through reactor A2. Leachate quality in both set-ups determined weekly for COD, BOD_5, ammonia nitrogen (NH_3-N) and ammonium nitrogen (NH_4-N). Multiple linear regression model was used to describe relationship between experiments data, furthermore equations of the fitted models and degree of accuracy by mean absolute error (MAE) were determined. The results indicate that this procedure has shown significant effect on reduction pollutant components of leachate, also it can be more effective for organic component removal compare to nitrogen removal.**

Index Terms—**Landfill simulation reactor, leachate pretreatment, nitrogen, organic component.**

I. Introduction

Solid waste is generated all over the world; traditional disposal of solid residues in landfills made the leachate a serious environmental problem. Landfill leachate is defined as a high strength wastewater generated as water and moisture collect contaminants and percolate through waste in a landfill. The risks from waste leachate are due to its high concentrations of organic contaminant, nitrogen compounds, heavy metals and other pollutants. Some of these organic pollutants are included in the list of priority pollutants of the environment and have been identified as potential sources of ground and surface water contamination if they are not properly treated and disposed of safely [1]. Thus, effective treatment of such wastewater is of great importance to reduce its adverse impacts. Several processes have been applied for the treatment of landfill leachates. Recent years, in response to the increasing production of leachate from the solid waste landfill, numerous leachate treatment methods have been developed and applied to treat landfill leachate, such as anaerobic and aerobic biological processes, coagulation flocculation, as well as chemical and electrochemical oxidation [2]. Leachate recirculation is also one of the methods to apply in bioreactor landfills to eliminate the leachate treatment and ground water contamination. The objective of all methods is to produce an environmentally safe fluid waste stream as much as possible.

The composition and concentration of contaminants in leachates are influenced mainly by the age of landfill [3]. There is not many alternative ways to remove organic and nitrogen compounds pollutants at one stage except biological methods [4]. The main goal of biological treatment is to interchange rapidly medium biodegradable compounds material strength in a short time. Therefore biological processes are quite effective when applied to relatively younger leachates containing mainly volatile fatty acids, while they are less efficient for the treatment of older leachates [5]. Testing these theories is difficult as a result of the heterogeneity of waste components, seasonality, costs and safety [6]. This is where laboratory scale models represents a simplified way to represent the reality under study, and allows to simulate the variations suffered both its quality and quantity from the elements of the system.

Considering the above problems and the current status of research in this field, the main aim of the present study was focused on evaluating the applicability of circulating fresh waste leachate on old deposits to remove organic and nitrogenous compounds from leachate. A series of laboratory experiments on landfill leachate from a laboratory scale model were conducted. BOD_5 and COD are stand for organic compounds while nitrogenous compounds are represented by NH_3-N and NH_4-N.

II. Experimental

Landfill simulation reactor (LSR) for laboratory scale modeling was applied to conduct the present study. All LSRs were constructed from a drum made of high density poly ethylene (HDPE) having a diameter of 500mm and a total height of 1000mm. Fig. 1 shows a schematic of LSR that was used for providing old waste in this study. The LSR equipped with a peristaltic pump allowing recirculation of leachate; the leachate recycling rate was 8L per day. LSR was filled with shredded municipal solid waste (MSW) having a density of approximately $1000 kg/m^3$ and composition of food waste 72%, paper 14%, plastic 2%, glass 4%, metals 6% and textile

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2%. Once a week 7L of leachate was withdrawn and replaced with tap water. This tap water corresponds to a precipitation input into the waste of around 1200mm. It corresponds to the condition when there is no impermeable surface sealing, only a permeable soil layer as cover. This value was obtained assuming that the net water input into the landfills equals the leachate amount generated. This assumption is justified by the fact that water storage becomes insignificant for the water balance of landfills when longer time periods are considered [7].

Parameters analyzed were pH, BOD5, COD, total dissolved solids (TDS), Conductivity (Con.), TKN, ammonia nitrogen (NH3-N), Nitrate-N nitrogen (NO3-N) and Sulfate (SO4). The techniques used for sampling analyses were in accordance with the Standard Method for the Examination of Water and Wastewater [8], except for TKN which was detected by Kjeldahl method. All analyses were undertaken at room temperature of 28±2°C except for conductivity and pH which were detected at 25°C and 23°C, respectively.

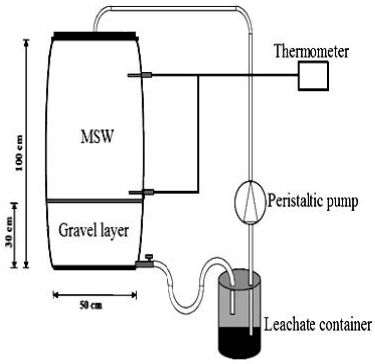

Fig. 1. Schematic LSR for providing old waste

In next step to establish the effect of old waste on pollutant removal, two different LSR systems were setup. Each set-up consists of two LSRs in series. LSRs specification was same with the previous step LSR. In the first set-up (Fig. 2) both reactors (A1 and B1) filled with fresh waste and their leachate was recirculated daily by peristaltic pump at constant rate. Waste composition was same with the waste that used in preparation of old waste. The function of second LSR is to have the same amount of waste in both system and eliminate the effect of waste volume on leachate analysis results. In the second set-up (Fig. 3), daily the leachate from fresh waste LSR (A2) was passed through the second LSR filled with old waste (B2) that was prepared in last step, while at the same time the leachate from reactor B2 was passed through reactor A2.

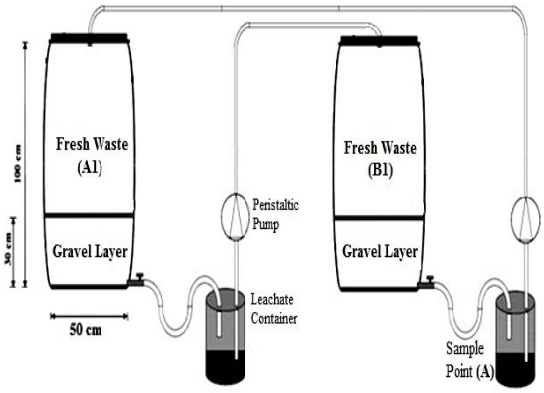

Fig. 2. Schematic Set-up1

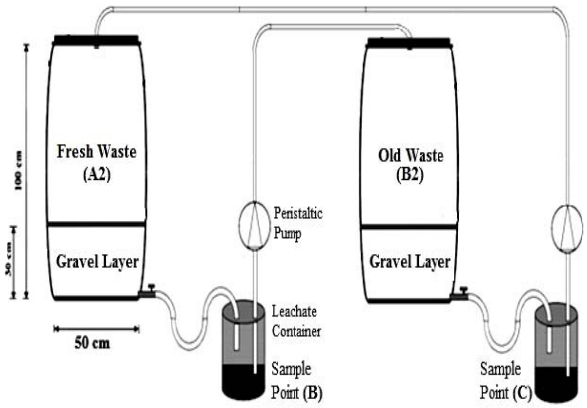

Fig. 3. Schematic Set-up2

III. Results and Discussion

A. Old Waste

For providing the old waste in set-up2 (LSR B2), an LSR with fresh waste (Fig. 1) had run until almost all of its parameters showed degradation for more than 90%. The characteristics of leachate from this LSR at different stages were tabulated in Table I. The whole duration of experiment was 130 days which in day 40 most of parameters have reached their maximum values. COD in leachate at initial and final day were 61,000mg/L and 4,830mg/L respectively, this indicates a non-biodegradable fraction of 0.08 was existed in experiment.

TABLE I: Leachate Parameters in Different Stages

Parameters	Day 15 (Initial)	Day 40 (Intermediate)	Day 130 (Final)
pH	5.71	5.44	6.16
Temperature (°C)	28±2	28±2	28±2
COD (mg/L)	61000	149000	4830
BOD_5 (mg/L)	47100	44900	3280
BOD_5/COD	0.77	0.3	0.68
TDS (mg/L)	15700	23700	1900
Con. (μS/cm)	26700	33400	2780
TKN (mg/L)	302	466	85
NH_3-N (mg/L)	299	45	69
NO_3-N (mg/L)	2.9	2.3	0.2
SO_4 (mg/L)	452	368	37

B. BOD_5 Removal

BOD is amount of oxygen required for the biodegradation of organic compounds. Fig. 4 demonstrates the variation of BOD_5 over time during degradation of waste in both set-up at different sampling points. It shows that the BOD_5 concentration at point A in set-up1 increased from its initial value of 5,560mg/L on day 3 to 73,120mg/L on day 17. It was followed by decreasing phase and reached 6,1260mg/L on day 60. At point B in set-up2, BOD_5 increased rapidly from 7,840mg/L to 87,000mg/L on day 17. From this day degradation phase started and on day 60 it reached to 38,400mg/L. At point C, BOD_5 attained to 11,980mg/L on day 60 from its initial value of 2,310mg/L. The degradation phase that accrues at point B was the effect of LSR B2. On day 60 point A showed 16% degradation in BOD, however at the same time point B in set-up2 showed 56% degradation.

Results confirmed that set-up2 was successful in organic pollutant removal from leachate. Anaerobic digestion due to microbial activity and dilution were responsible for this extra 40% in BOD_5 concentration reduction.

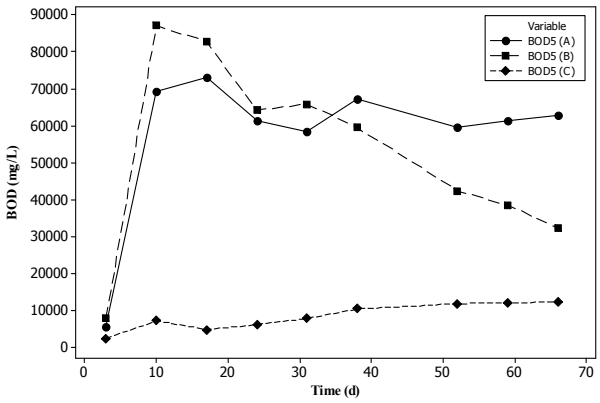

Fig. 4. Profile of BOD_5 in sampling points A, B & C

C. COD Removal

COD determine the amount of organic compounds in water and wastewater indirectly. Fig. 5 shows COD and time profiles. At point A COD on day 17 and day 60 were almost same; this means it did not show any degradation at mentioned period. However, at the same period at point B COD from 166,000mg/L decreased to 90,000mg/L while in point C, it increased to 33,200mg/L from 4,710mg/L. While point A did not show any degradation in COD, point B showed 46% degradation. This indicates set-up2 was effective in removal of organic compounds and reduced the organic compounds in leachate significantly.

At point A, COD increased from 12,100 mg/L on day 3 to maximum value of 180,000mg/L on day 27 but as it shows in Fig. 4, BOD reached its maximum value on day 17. In other way there is 10 days between BOD and COD extrema. This phenomenon was caused by soluble microbial product (SMP) which is in contributed to the COD value in the effluent. SMP are soluble cellular components that are released during biomass decay, they are inevitably produced because of microbial metabolism. The main components of SMP have been identified as protein, polysaccharides, humic acids, and nucleic acids [9]. SMP are important because they are always formed during biological treatment, and they constitute the majority of the effluent COD in many cases [10]. Various articles have proven that formation of SMP in anaerobic system indeed contributed to a certain percentage of COD in the effluent [11, 12].

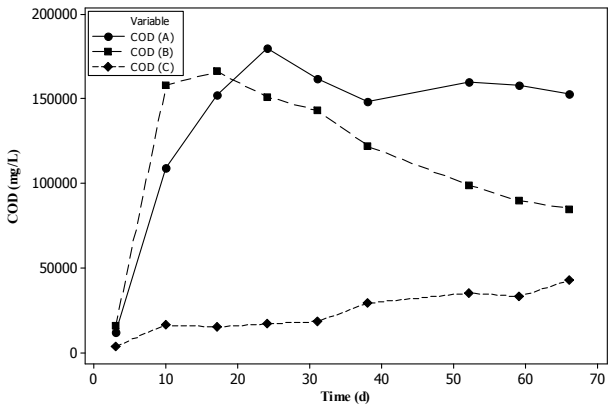

Fig. 5. Profile of COD in sampling points A, B & C

D. BOD_5/COD

BOD_5/COD ratio describes the biodegradability level of materials by which organic matter containing leachate is readily broken down in the environment. It is known that BOD_5/COD ratio of leachate decreases with time in landfill, resulting in the stability of leachate. It decreases rapidly from 0.70 to 0.04 with the aging of the landfills [13]. BOD_5/COD ratio for sampling points in both set-ups demonstrate in Fig. 6, all points are showing descending pattern in this ratio. The maximum value of 0.63 had obtained for point A and minimum value of 0.28 obtained for point C. Results indicate set-up2 shows better behavior in reducing the ratio compare to set-up1. At the end of experiment point A showed higher ratio compare to other points, which means the degree of solid waste stabilization in set-up1 did not reach to stable level yet, also it may indicate that portions of the waste are still in the acid phase [14].

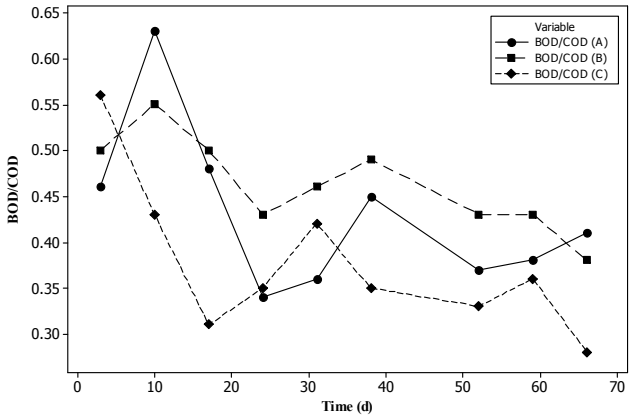

Fig. 6. BOD/COD ratio in sampling points A, B& C

E. N Removal

Nitrogen removal efficiency was carried out by determination of ammonia nitrogen (NH_3-N) and ammonium nitrogen (NH_4-N) in both set-ups. Ammonia and ammonium changes at different sampling points were shown in Fig. 7 and Fig. 8, respectively. It was found that ammonia nitrogen and ammonium nitrogen were linked together directly. Ammonia concentration from 409mg/L on day3 reached 1,336 mg/L on day 60 in point A but point B only increased to 960mg/L from 490mg/L at same period of time. Ammonium concentration from 434mg/L on day3 reached 1,367 mg/L on day 60 in point A but point B only raise to 1,006mg/L from 538mg/L at same period of time.

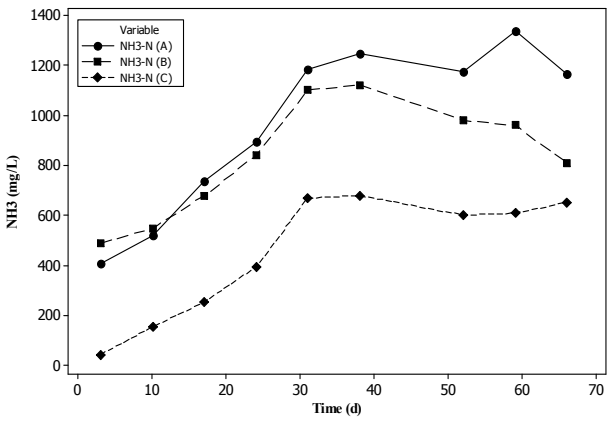

Fig. 7. Profile of NH_3 in sampling points A, B & C

Point B shows 28% and 26% lower concentration respectively in ammonia and ammonium compare to point A. This shows applicability of this method on nitrogen removal. Degradation processes of fresh waste due to microbial activity are responsible for nitrogen compound in leachate. The ammonia and ammonium concentrations have remained elevated which is consistent with the absence of nitrifying bacteria for nitrification under anaerobic conditions. Adsorption onto the old waste surface was the only reason of reduction in ammonia and ammonium concentrations in set-up2. That explains why the performance of this method was lower in nitrogen removal compare to organic compounds.

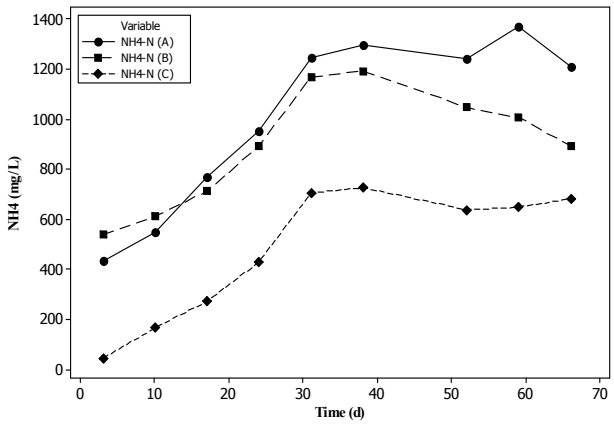

Fig. 8. Profile of NH_4 in sampling points A, B & C

F. Regression Analysis

The goal of regression analysis was to determine the values of parameters for a function that cause the function to best fit the experiments data. Multiple linear regression models were used to describe the relationship between concentration of different parameters in point B as the dependent parameters and concentration of different parameters in point A and time in day as independent variables. Regression analysis was performed using multiple linear regression procedure in statistical package of Statgraphics-Centurion software package [15]. The equations of the fitted models and the correspond mean absolute error (MAE) summarized in equations 1 to 5. MAE is measure of accuracy in forecasts or predictions to the eventual outcomes. These equations may be used to predict concentration parameters to evaluate the performance of this method at any desire time period. For this matter appropriate approach to extrapolate data from LSR experiment to site condition should be considered.

$$BOD5\ (B) = 4455.38 + 1.29653(BOD5\ (A)) - 773.207T \quad (1)$$
(MAE) = 2530.82

$$COD\ (B) = 24152.2 + 1.0817(COD\ (A)) - 1741.64T \quad (2)$$
(MAE) = 12140

$$BOD/COD\ (B) = 0.379038 + 0.294709\ (BOD/COD\ (A)) - 0.0012827\ T \quad (3)$$
(MAE) = 0.0147327

$$NH3\text{-}N\ (B) = 76.0026 + 1.05163(NH3\text{-}N\ (A)) - 7.55458T \quad (4)$$
(MAE) = 26.4294

$$NH4\text{-}N\ (B) = 106.612 + 1.01412(NH4\text{-}N\ (A)) - 6.95143T \quad (5)$$
(MAE) = 32.7403

IV. Conclusions

The results indicate that fresh waste leachate by circulating on old waste deposits method has capability to use as a pretreatment in organic component and nitrogen removal. Also, organic component removal performance was higher than nitrogen removal because the only process that is responsible for nitrogen removal is adsorption onto the old waste surface. Furthermore equations base on fitted models on experimental data by using regression analysis were determined. These equations may be helpful in prediction of method performance in any time period.

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