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### DESIGN OF AMMONIUM STRIPPING TOWER AND OPTIMIZATION OF AMMONIUM REMOVAL FROM LANDFILL LEACHATE

### AMONYUM SIYIRMA KULESİ DİZAYNI VE ÇÖP SIZINTI SUYUNDAN AMONYUM GİDERİMİ OPTİMİZASYONU

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#### ABSTRACT

Landfill leachates are complex wastewater which has high pollution and their biological degradability is also difficult. Landfill leachate with high concentrations of contaminants must be pretreated. For this reason, the ammonium stripping process is an effective method for ammonium removal, especially for landfill leachate. With the ammonium stripping process, the ammonium and organic matter removal increases. This study aimed to investigate the applicability of the ammonium stripping process as remove ammonium (NH<sub>4</sub><sup>+</sup>) and chemical oxygen demand (COD) from raw leachate. A new system has been designed which is called ammonium stripping tower. During this study, the ammonium stripping process was operated temperature (30-40-60°C), aeration rate (HH, HL, LL m<sup>3</sup>air/min), and hydraulic retention times (6-12-24-48 h). System performance was evaluated by ammonium, and COD parameters. The optimum conditions of the ammonium stripping process were determined at 60°C temperature, HH(1m<sup>3</sup>air/min aeration rate), and hydraulic retention time (48h). The corresponding ammonium and COD removal efficiencies were about 88% and 79% respectively. The results of this study suggest that the use of an ammonium stripping process is an effective way to remove ammonium and COD concentration from raw landfill leachate.

**Keywords:** Physicochemical treatment, landfill leachate, ammonia removal, ammonia stripping proces

#### ÖZET

Düzenli depolama sahalarındaki sızıntı suları, yüksek kirliliğe sahip karmaşık atık sulardır ve biyolojik olarak parçalanabilirlikleri de zordur. Yüksek konsantrasyonlarda kirletici madde içeren deponi sahası sızıntı suyuna ön arıtma yapılmalıdır. Bu nedenle, amonyum sıyırma işlemi, özellikle sızıntı suyunun amonyum giderimi için etkili bir yöntemdir. Amonyum sıyırma işlemi ile amonyum ve organik maddelerin giderimi artar. Bu çalışmada, amonyum sıyırma işleminin ham sızıntı sularından amonyum (NH<sub>4</sub><sup>+</sup>) ve kimyasal oksijen ihtiyacı (KOİ) giderilmesinin uygulanabilirliği araştırıldı. Amonyum sıyırma kulesi adı verilen yeni bir sistem tasarlanmıştır. Bu çalışma sırasında amonyum sıyırma işlemi, sıcaklık (30-40-60°C), havalandırma oranı (HH, HL, LL m<sup>3</sup>air / dak) ve hidrolik bekletme süreleri (6-12-24-48 saat) olarak gerçekleştirildi. Sistem performansı amonyum ve KOİ parametreleri ile değerlendirildi. Amonyum sıyırma işleminin optimum koşulları 60°C sıcaklık, HH (1m<sup>3</sup>hava/dakika) havalandırma hızı ve (48 saat) hidrolik bekletme süresi belirlenmiştir. Karşılık gelen amonyum ve KOİ giderim verimleri sırasıyla yaklaşık % 88 ve % 79'dur. Bu çalışmanın sonuçları, bir amonyum sıyırma işleminin kullanılmasının, ham depolama sahası sızıntı sularından amonyum ve KOİ konsantrasyonunu gidermek için etkili bir yöntem olduğunu göstermektedir.

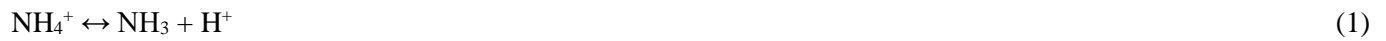
**Anahtar Kelimeler:** Fizikokimyasal arıtım, çöp sızıntı suyu, amonyum giderimi, amonyum sıyırma prosesi

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## INTRODUCTION

The regular storage method is cheaper and easier to maintain than other technologies. Therefore, it is generally used for garbage treatment and disposal. However, the major environmental concern of this method is the generation of large quantities of liquid leachate, which may cause serious pollution to groundwater aquifers as well as adjacent surface waters (Calace, N., et al., 2001). Because the landfill leachates treatment is very complex and expensive, it often needs a variety of applications in terms of high COD, ammonium concentrations and color. Various aerobic and anaerobic treatment systems have been applied to the treatment of leachate and high treatment efficiency has been achieved. However, with these systems, various problems have occurred depending on the age of the landfill leachate (Ledakowicz S., & Kaczorek, K., 2001). Landfill leachate contaminant contents depend upon the landfill age, the quality. Since the wastes coming to the storage area may contain many types of pollutants, if these wastes are not properly collected, treated and disposed of safely, they can cause serious environmental hazards. Biological treatment systems are no longer available alone and refractory organic materials are not sufficient to go through, so additional purification is needed. Physico-chemical systems are widely used as pretreatment and these systems; ammonium stripping, ion exchange, chemical precipitation, coagulation-flocculation, flotation and adsorption. Ammonium stripping is the most common purification system used to remove ammonia from landfill leachate (Collivignarelli, C., et al., 1998); (Martinen, S., et al., 2002). In the ammonium stripping process, the transition from the liquid phase to the gas phase depends on a mass transfer. That is, the ammonium ions ( $\text{NH}_4^+$ ) in the liquid phase are in equilibrium with ammonia ( $\text{NH}_3$ ) in the gas phase and hydrogen ions ( $\text{H}^+$ ). Briefly, ammonium stripping can be expressed by the following equation (Hossini, H., et al., 2016):



When the pH of the wastewater rises above 7, the balance shifts to the right. When the pH rises above 10, the ammonium ions turn into ammonia gas under the influence of air and separate from leachate. In the ammonium stripping process, volatile organic compounds are separated from the aqueous solution by maximum specific contact between liquid and air in a specially designed column (Hossini, H., et al., 2016). The landfill leachate must have a pH above 10 to achieve maximum ammonium removal efficiency. Here,  $\text{Ca}(\text{OH})_2$  is preferred because it is an alkali that is both economical and effective in increasing pH. Advantages of using  $\text{Ca}(\text{OH})_2$  include the removal of heavy metals and colors caused by co-precipitation of organic macromolecules, such as humic acids in the leachate (Renou, S., et al., 2009). It can also be said that high temperatures are used as an alternative method of providing high ammonium removal in the ammonium stripping process.

The objective of this paper was to investigate the pretreatment of landfill leachate physicochemical stage. Four experimental parameters have been tested during the study: (i) the reactor design and supply of the necessary consumables have been provided. (ii) the effect of different temperature parameters (30,40,60°C), (iii) the effect of high((HH)1m<sup>3</sup>air/min), medium((HL)0,85m<sup>3</sup>air/min) and low((LL)0,75 m<sup>3</sup>air/min) aeration rate and (iv) different hydraulic retention times(HRT) (6, 12, 24 and 48 h) on ammonium stripping. As a result of these studies, optimum conditions have been obtained by examining the ammonium and COD removal efficiencies and this study will help the projects on the future ammonium stripping processes.

## MATERIALS AND METHODS

### *Characterization of Landfill Leachate*

The landfill leachate from the municipal sanitary landfill of Kahramanmaraş that has an average 1.127.623 inhabitants and productions 2,23 kg/person of municipal solid waste per day. Samples were monthly taken from

aeration lagoon all samples were instantly stored at 4°C before applying ammonium stripping. The landfill leachate characterization shown in Table 1.

**Table I.** Characterization of Landfill Leachate

Parameter	Concentration (mg/L)
pH	8,87
COD	7500
Color (Pt-Co)	8380
Color (436)	297
Color (525)	88
Color (620)	37
Ammonium	2215
Nitrate	410
TOC	4432
TN	2506
SS	800

### Experimental Plan

Ammonium stripping processes were performed using ammonium stripping towers. This ammonium stripping tower has been designed by choosing Plexiglass material for its resistance to temperature, impacts and various adverse conditions. The dimensions of the ammonium stripping tower with 3 L internal volume are designed as 10x8x40 cm. The interior design of the reactor consists of three compartments. The sieves consisting of two plexiglass materials at a certain distance between each other were placed and filled with 400 K3 sized caldnesses which were determined as filling materials. Air ports, one of the operating parameters, are installed in each chamber of the three chambers, which play a role in determining the airflow. Ammonium stripping experiments were carried out under various temperature (30, 40 ve 60°C), aeration rate (1m<sup>3</sup>air/min(HH(high))-0.85m<sup>3</sup>air/min(HL)-0.75m<sup>3</sup>air/min(LL)) and hydraulic retention time (6,12,24,48 h) values in order to determine optimum temperature conditions. In the first period, the effect of temperature was evaluated on ammonium stripping. Then, the performance of aeration rate was investigated during period II and determined to hydraulic retention time. The operational conditions of ammonium stripping tower were given in Table II. The most appropriate methods have been established in the direction of the operational optimum condition.

**Table II.** Experimental Plan

PHASE	PERIODS	TEMPERATURE (°C)	AERATION RATE (m <sup>3</sup> air/min)	HRT(h)
I. Phase Reactor design	-	-	-	-
II. Phase Optimization of different temperature values	I	30	H H	48
	II	40		
	III	60		
III. Phase Optimization of different aeration rates	IV	Opt.	H H	48
	V		H L	
	VI		L L	
IV. Phase Optimization of Different Leachate	VII	Opt.	Opt.	48
	VIII			24
	IX			12
	X			6

The reactor has been placed on the kaldnesses worked with 1.65L landfill leachate. High, medium and low flow rates are provided between each chamber with the help of oxygen pumps. The ammonium stripping tower used in the study is shown in Figure I.

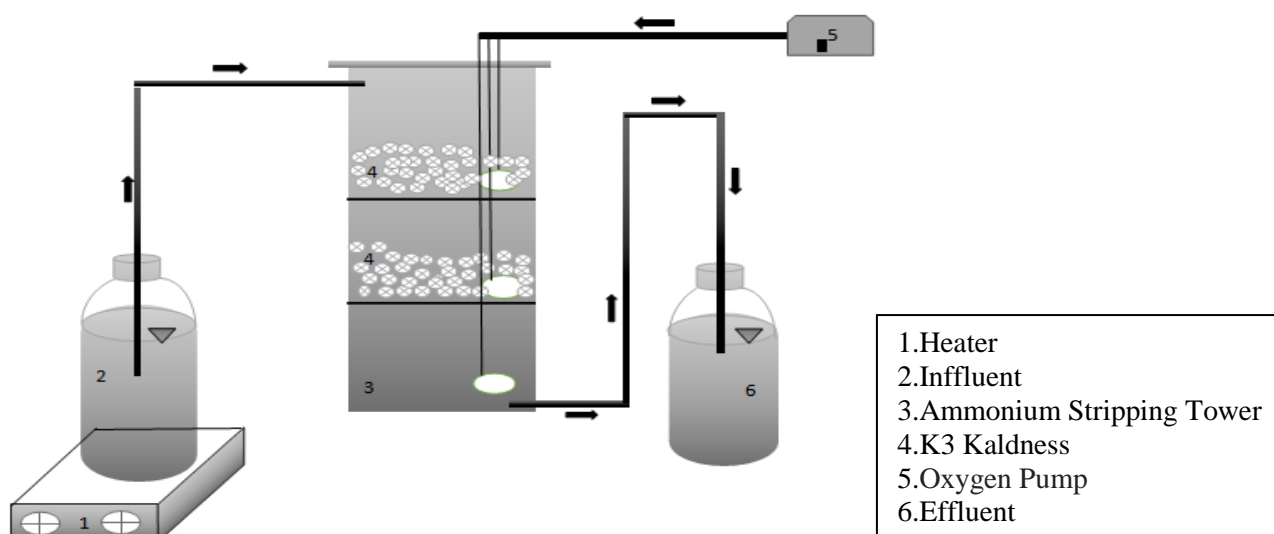


Fig. I. Schematic diagram of Lab-scale ammonia stripping tower

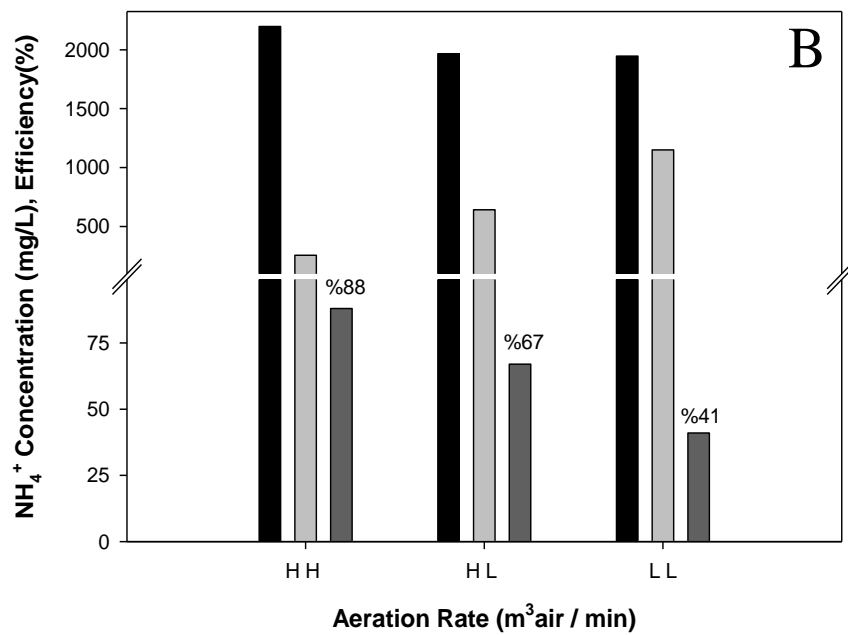
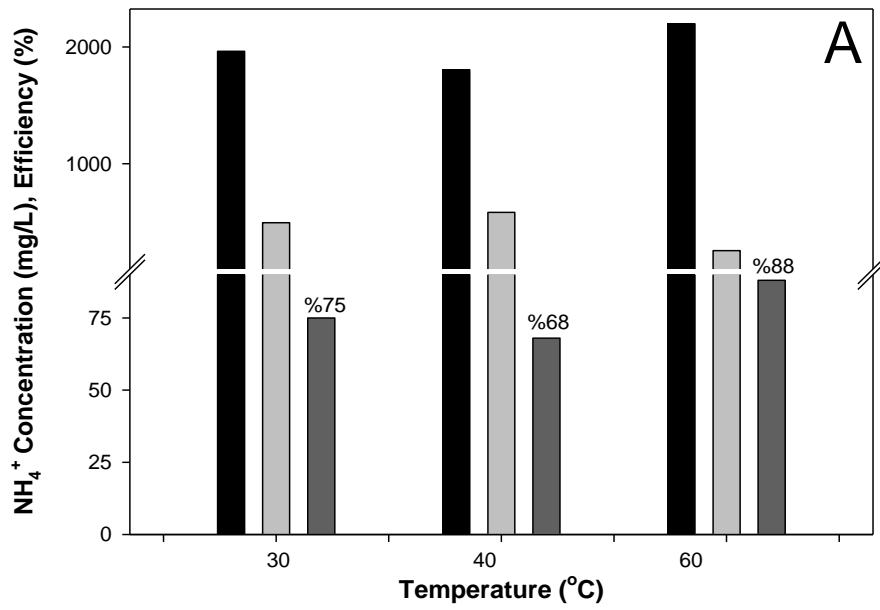
### Analyses

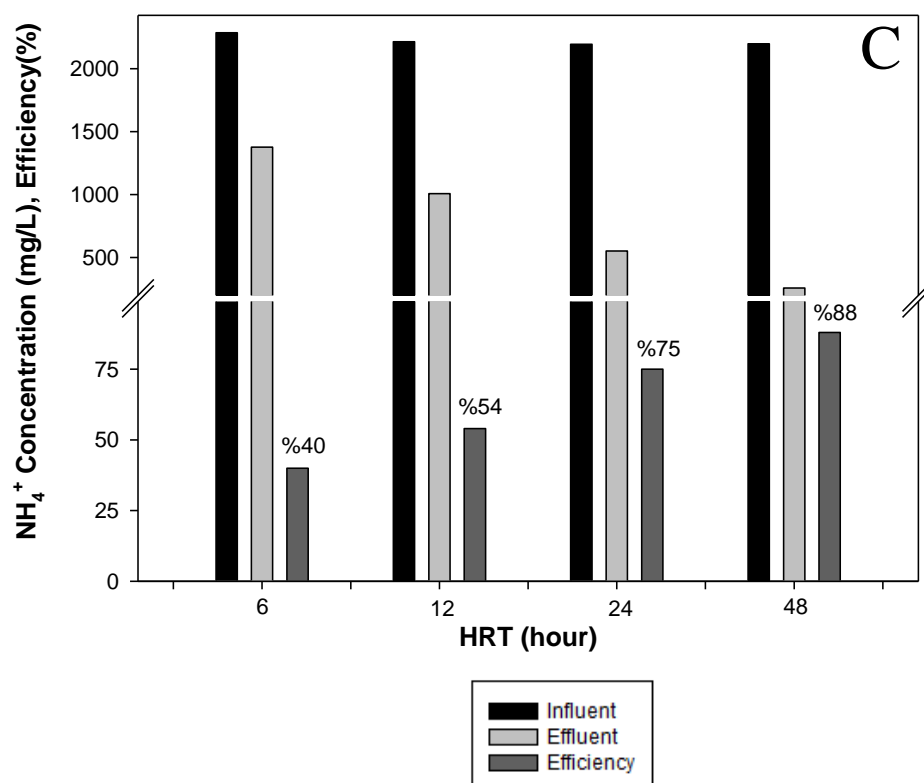
Before all analysis, liquid samples were centrifuged (Eppendorf Centrifuge 5415R, Hamburg, Germany) at 4000 rpm for 5 min and then supernatant was filtered through a 0.45- $\mu$ m pore size syringe filter. The COD analysis were performed by the dichromate closed reflux method in accordance with Standard Methods 5220D. pH was measured with a multimeter (340i, WTW, Oslo, Norway). The concentrations of ammonium, nitrate ions were determined by an ion chromatography (Dionex ICS-3000, Sunnyvale, CA, Japan) with IonPac AS19 analytical and Ion-Pac AG19 guard columns. Eluent was prepared from 9 mM sodium carbonate and 20 mM methane sulfonic acid and was pumped at flow rate of 1 ml/min.

## RESULTS AND DISCUSSION

### Ammonium Removal Performance

Ammonia stripping is the most common process for eliminating  $\text{NH}_4^+$  involved in leachate wastewater treatment technologies. The process involves the passage of large quantities of air over the exposed surface area of leachate, thus causing the partial pressure of the ammonia gas within the water to drive the ammonia from the liquid to the gas phase. The value of temperature, retention time and aeration rate are the main parameters effected on the  $\text{NH}_4^+$  removal ratio in this process. The effect of these parameters on ammonium removal during pre-treatment of LFL is demonstrated in Figure II.



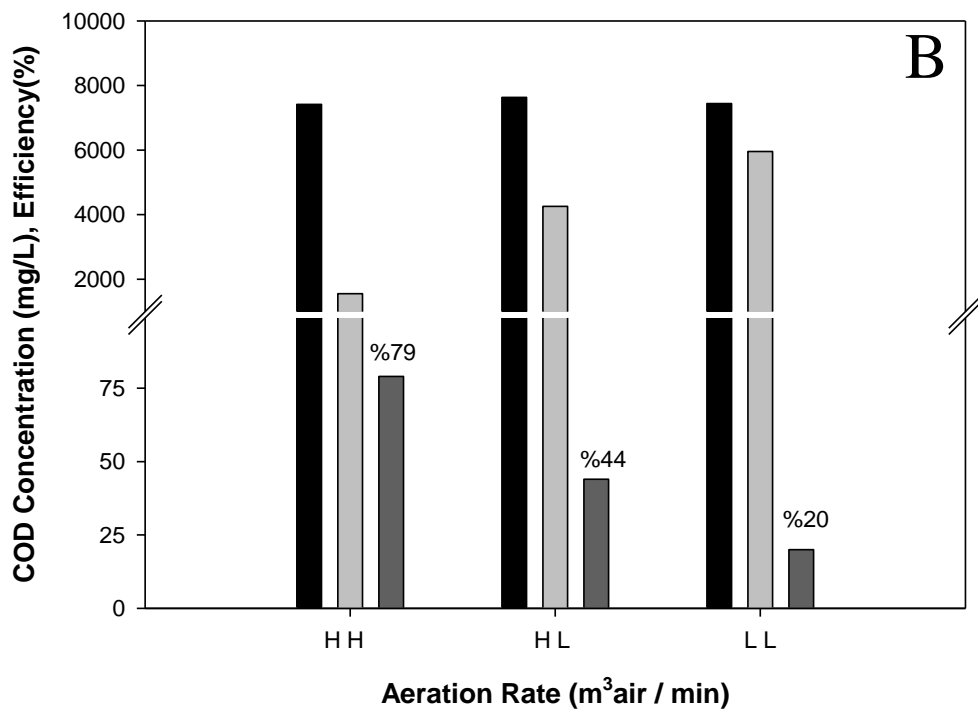
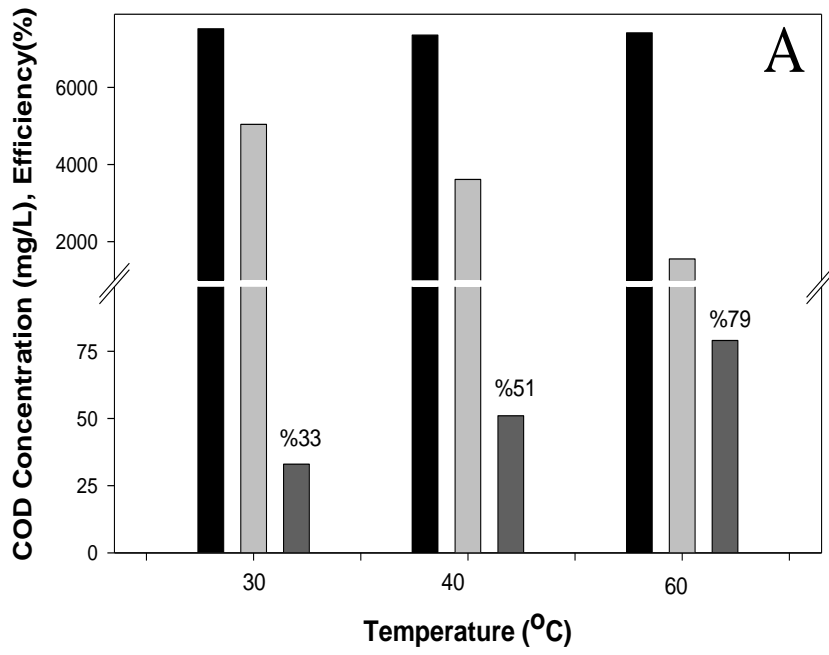


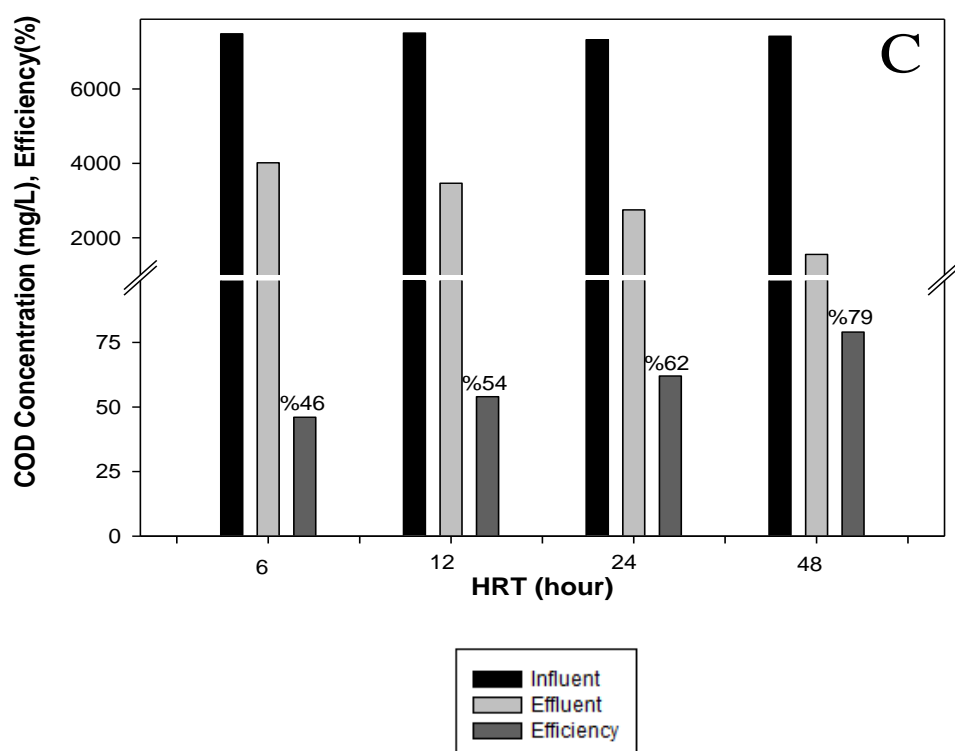
**Fig. II.** The effect of  $\text{NH}_4^+$  concentration removal by ammonium stripping: (A) Temperature, (B) Aeration rates and (C) Hydraulic retention times

Figure IIA shows the effect of temperature on  $\text{NH}_4^+$  removal efficiency. The removal ratio increased significantly with increases in the temperature.  $\text{NH}_4^+$  removal was about 75, 68 and 88 % at 30, 40 and 60 °C, respectively (Göçer, S., et al., 2018). reported the removal efficiency of  $\text{NH}_4^+$  at 60°C as 80%. Higher removal efficiency has been achieved in the study conducted with the ammonium stripping tower. As a result, the temperature of 60 °C should be the optimum because the removal efficiency is significantly increased. Figure IIB shows the effect of high, medium, and low aeration rates on  $\text{NH}_4^+$  removal efficiency. The highest  $\text{NH}_4^+$  removal efficiency was obtained at the high air rate corresponding to 88% (Cheung, K., et al., 1997). investigated airflow rate and pH as critical parameters for the optimization of ammonia stripping in a stirred tank. After one day, they achieved significant ammonia removal efficiency between 86 and 93% at the aeration rate of 5ml/min and pH greater than 11. Figure IIC shows the effect of hydraulic retention time on  $\text{NH}_4^+$  removal efficiency. Under optimum conditions, 6, 12, 24 and 48 h retention times have been tested and  $\text{NH}_4^+$  removal efficiencies have been respectively 40%, 54%, 75%, and 88%. Optimum retention time has been determined as 48 h.

### **COD Removal Performance**

The value of temperature, aeration rate and retention time are the main parameters affected on the COD removal efficiency in the ammonium stripping process (Figure III). The effect of temperature (30-40-60 °C) on the efficiency of COD removal was investigated (Fig IIIA). The removal efficiency has increased considerably with increasing temperature. An increase in temperature to 30-40-60 °C, had a positive effect on COD removal efficiency which was approached to 33%, 55% and 79% respectively. Therefore, the optimum temperature was 60°C. Figure IIIB shows the removal of COD by different aeration rates at ammonia stripping process. The COD removal efficiency increased significantly with increases in the aeration rate. The increasing aeration rate from LL to HL and HH ( $\text{m}^3\text{air}/\text{min}$ ) increased COD removal which approached to 79%, 44% and 20% respectively. The maximum COD removal efficiency of 79% was obtained in the aeration rate HH ( $\text{m}^3\text{air}/\text{min}$ ). Fig. IIIC shows the effect of COD removal by ammonium stripping processes at different HRT (6-12-24-48 h). The effect of hydraulic retention time on COD removal efficiency is shown in Figure IIIC. The highest COD removal efficiency has been reached in 48 hours and the removal efficiency has been 79%. Increased hydraulic retention time has decreased COD concentration (Hanira, N., et al., 2017).





**Fig. III.** The Effect Of COD Concentration By Ammonium Stripping: Temperature(A),  
Aeration Rates(B) And Hydraulic Retention Times(C)

## CONCLUSION

Ammonium stripping process in terms of physicochemical treatment of LFL performance was investigated. The following conclusions are drawn based on the results of the study:

- A new system (ammonium stripping tower) has been designed under laboratory conditions.
- The optimum conditions for the ammonia stripping process are determined as temperature (60°C), hydraulic retention time (48 h) and high aeration rate (1 m<sup>3</sup> air/min).
- In optimum conditions, the highest removal efficiencies have been 88% for NH<sub>4</sub><sup>+</sup> and 79% for COD.
- This study presents an alternative treatment technique for physicochemical treatment.

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