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Planted Batch System Treating Leachate

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Abstract

The aim of this study was investigation of changes in the nutrients and COD, pH and electrical conductivity in two batch systems planted with *Lemna gibba* L. to treat leachate. For this aim NH_4^+-N, NO_2^--N, NO_3^--N, O-PO_4^{3-}, COD, pH and electrical conductivity were determined. Experimental studies were established in batch systems with two various depths (5 cm and 10 cm) and various hydraulic retention times. Removal efficiencies which were obtained for NH_4^+-N and O-PO_4^{-3} in the batch reactors with depth of 5 cm were between 40.4-70.2% and 18.8-32.0%, respectively and in the batch reactors with depth of 10 cm were between 39.8-68.1% and 18.2-27.2%, respectively. The NO_2^--N and NO_3^--N concentrations of effluents were higher than the initials. Removal efficiencies which were obtained for COD in the batch reactors with depth of 5 cm were between 52.0-58.0% and in the batch reactors with depth of 10 cm were between 51.1-55.4%. pH of the leachate which had an initial value of 7.91 reached to a maximum of 8.50. Conductivity which had an initial value of 5.59 mS/cm reached to a maximum of 8.04 mS/cm.

Keywords: Nutrient, *Lemnaceae* species, leachate, nitrification, removal

Sızıntı Suyunu Arıtan Bitkili Kesikli Sistem

Özet

Bu çalışmanın amacı, sızıntı suyu arıtımı için *Lemna gibba* L. ile bitkilendirilmiş iki kesikli sistemde nutrientlerin ve KOİ, pH ve elektriksel iletkenliğindeki değişiminin araştırılması olmuştur. Bu amaç için, NH_4^+-N, NO_2^--N, NO_3^--N, O-PO_4^{3-}, KOİ, pH ve elektriksel iletkenlik belirlenmiştir. Deneysel çalışmalar farklı hidrolik alıkonma sürelerinde ve iki farklı derinlikte (5 cm ve 10 cm) kesikli sistemlerde gerçekleştirilmiştir. 5 cm derinlikteki kesikli reaktörlerde NH_4^+-N ve O-PO_4^{-3} için elde edilen giderim verimleri sırasıyla %40,4-70,2 ve %18,8-32,0 arasında, 10 cm derinlikteki kesikli reaktörlerde ise sırasıyla % 39,8-68,1 ve %18,2-27,2 arasında olmuştur. Çıkış sularının NO_2^--N ve NO_3^--N konsantrasyonları giriştekilerden yüksek olmuştur. KOİ için elde edilen giderim verimleri 5 cm derinliğe sahip reaktörlerde %52,0-58,0 arasında, 10 cm derinliğe sahip reaktörlerde %51,1-55,4 arasında olmuştur. Sızıntı suyunun başlangıçta 7,91 olan pH değeri, en yüksek 8,50 değerine ulaşmıştır. 5,59 mS/cm' lik başlangıç değerine sahip iletkenlik, en yüksek 8,04 mS/cm değerine ulaşmıştır.

Anahtar Kelimeler: Nutrient, *Lemnaceae* türleri, sızıntı suyu, nitrifikasyon, giderim

1. Introduction

Most organic matter in the solid waste are biodegradable and can be broken down into simpler compounds by anaerobic and aerobic microorganisms, leading to the formation of leachate [1, 2]. Leachate may be defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials. In most landfill, leachate is composed of the liquid that has enter the landfill from external sources, such as surface drainage, rainfall, groundwater and water from underground springs and the liquid produced from the decomposition of the wastes [3]. Leachate characteristic is similar to toxic waste due to content of heavy metal such as manganese, ferum, cadmium and lead [3, 4] . The leachate may migrate from the refuse and contaminate the surface water and ground water. Thus, the amount of leachate of solid waste in a location where it exist affects the quality of groundwater and surface water. Dissolved substance transport is a major polluting threat for surface and ground water [5].

Leachate (containing heavy metals, toxic, organic compound, acidity) has several adverse effects on the human health such as carcinogenic systems, skin disorders, neuro-toxicity, kidney damage, suppressed immunity, digestive disorders, as well as adverse effects on flora and fauna. Since leachate can affect aquatic ecosystems and human health, proper leachate treatment is needed before leachate is discharged into receiving water [3]. Treatment of leachate constitutes a considerable problem in landfill management. For the on-site treatment of leachate, a combination of several biological, chemical and physical-chemical processes has been proposed in order to respect limits for effluent discharge. The main problems of these solutions (such as those based on reverse osmosis) are the high cost and the complexity of management, so that they are often not practicable under limiting economical conditions (e.g. developing countries) [6]. Therefore, cheap but effective treatment technologies were investigated [7]. As a result, aquatic planted systems as well as the removal of wastewater for treatment of complex water, requiring a low cost and a minumum of manpower, energy consumption is very low and it is accepted as an alternative technology [6].

Although it is difficult to define the characteristics of leachate generated during the landfill treatment and disposal of municipal solid waste since the leachate composition and concentration depend on factors such as the composition of wastes, age of landfill, geology, temperature, and moisture content [8, 9], it is generally accepted that leachate contains a large amount of organic and inorganic contaminants, such as high COD, BOD_5 and ammonium concentration, and sometimes, high concentrations of metals and hazardous organic chemicals [9, 10]. Leachate consists of many different organic and inorganic compounds that may be either dissolved or suspended and which are biodegradable and non-biodegradable [11, 12].

Organic contaminant is one of the problematic parameter in landfill leachate treatment [13] and disposal. Landfill leachates are often disposed to municipal sewers, where available. However, mature leachate characterized by low BOD_5/COD ratio (<0.3) and high fraction of high molecular-weight organics is particularly challenging due to low biodegradable fraction of the organics and constituent toxicity to biological process [14].

The hydrogen-ion concentration is an important quality parameter for both natural waters and wastewaters. The concentration range suitable for the existence of most biological life is quite narrow and critical. Wastewater with an adverse concentration of hydrogen-ion is difficult to be treated by biological means, and if the concentration is not altered before the discharge, the wastewater effluent may alter the concentration in the natural waters [15]. Salinity of water is determined by measuring its electrical conductivity. The electrical conductivity of water is used as surrogate measure of total dissolved solids concentration. The presence of salts affects plant growth in three ways: (1) osmotic effects, caused by the total dissolved salt concentration in the soil water; (2) specific ion toxicity, caused by the concentration of an individual ion; and (3) soil particle dispersion, caused by high sodium and low salinity [15].

Duckweed is a floating aquatic macrophyte belonging to the botanical family *Lemnaceae*, which can be found world-wide on the surface of nutrient rich fresh and brackish waters [16, 17]. *Lemna gibba* L. (duckweed) is an important, fast growing tested organism. It is an aquatic plant and is relevant to many aquatic environments, including lakes, streams, and effluent. Additionally, duckweed is a vascular, flowering plant. It is known that under laboratory conditions its biomass can be doubled at 24-48h under optimal nutrient supply, appropriate illumination and temperature of 25-29 ^{0}C [18, 19]. Applications of *Lemna gibba* L. (duckweed) in wastewater treatment was found to be very effective in the removal of soluble salts, organic matter, heavy metals and in eliminating suspended solids, algal abundance and total and fecal coliform densities [17].

In this study, changes of NH_4^+-N, NO_2^--N, NO_3^--N, O-PO_4^{3-}, COD, pH and electrical conductivity in batch systems planted with *Lemna gibba* L. to treat leachate were examined at different hydraulic retention times (HRT) and depths.

2. Materyal and Method

2.1 Material

The leachate samples used as material in our research were obtained from the leachate pond of the wild storage area of Sivas City (Turkey). Samples were taken from 15 different points (Figure 1) and mixed homogeneously. *Lemna gibba* L. was obtained from the natural environment (Elazıg City, Turkey). The characteristics of leachate used in the experiments are given in the Table 1. Reactors used in our research are made from glass with dimention of 15x45x15 cm which consist of 9 divisions (Figure 2). Two reactors were used as controls and two reactors were planted with 15.5 gr (ww) *Lemna gibba* L. with leachate depths of 5 and 10 cm. The batch systems were maintained at room temparature. The dissolved oxygen (DO) (3 mg/l) were given by diffusers. The reactors were lightened by 60 watt fluorescent lamb by the period of 12 hours daylight and 12 hours dark.

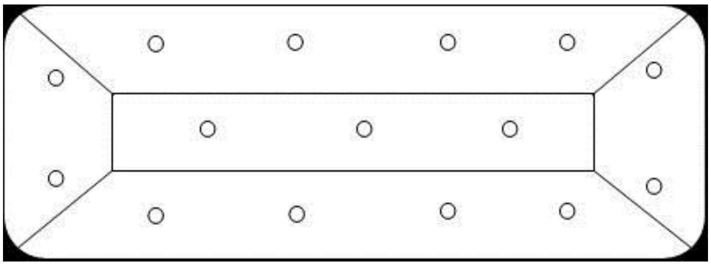

Fig 1. The sampling points.

Table 1. The characteristics of leachate.

Parameter	Value
pH	7.91
Electrical Conductivity (EC) (mS/cm)	5.59
COD (mg/l)	610.0
BOD_5 (mg/l)	90.0
BOD_5/COD	0.147
NH_4^+-N (mg/l)	0.54
NO_2^--N (mg/l)	0.79
NO_3^--N (mg/l)	18.0
O-PO_4^{-3} (mg/l)	13.0

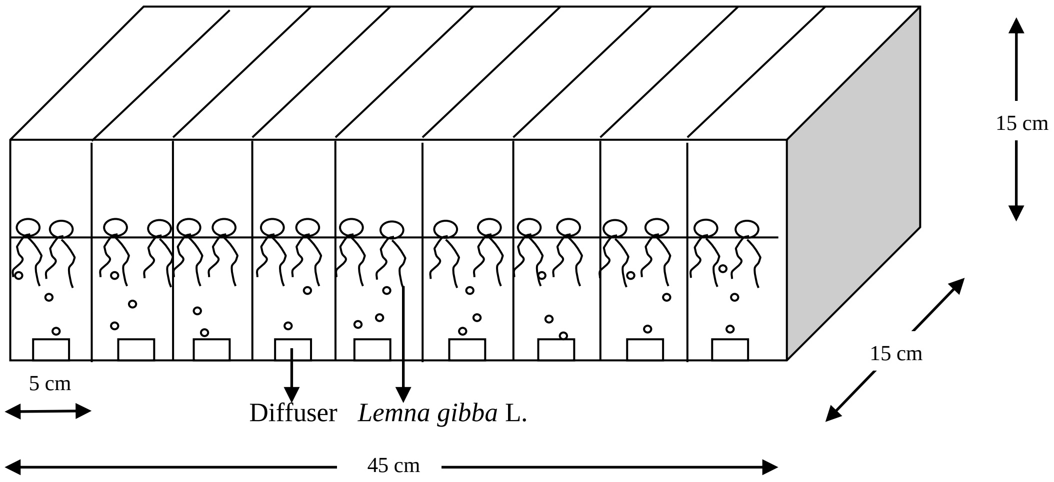

Fig 2. The system used in this study.

2.2 Method

The experiments were done according to the Standard Methods [20]. EC and DO were measured by Hach Lange HQ40d EC and DO meter. pH were measured by Hanna pH211 Instruments Microprocessor pH Meter, respectively.

3. Results and Discussion

3.1 Ammonium Nitrogen (NH_4^+-N)

The NH_4^+-N removal efficiencies according to the various HRT and depths were given in Figure 3. HRT efficiency effected the removal capacities. The NH_4^+-N removal efficiencies increased with the increase in HRT. The maximum removal efficiency was 70.2% in the planted reactor with a depth of 5 cm at HRT of 9 days. The removal of NH_4^+-N was due to the plant uptake of the ammonium for the need of nitrogen. The removal capacity decreased with the increase of depth from 5 to 10 cm. The efficiency decrease is only attributed to the decreasing amount of duckweed per m^3 reactor [21]. The removal efficiencies in unplanted reactors with a depth of 5 and 10 cm were 40.4 and 39.8% at day 9, respectively. The NH_4^+-N removal efficiencies in the planted reactor with a depth of 10 cm was 68.1% at day 9. *Lemna gibba* L. significantly increased the efficiency. Duckweed prefers uptake of ammonia to nitrate since nitrogen in the ammonium form is trasformed directly to plant protein rather than being assimilated and subsequently reduced as in the case of nitrate [22].

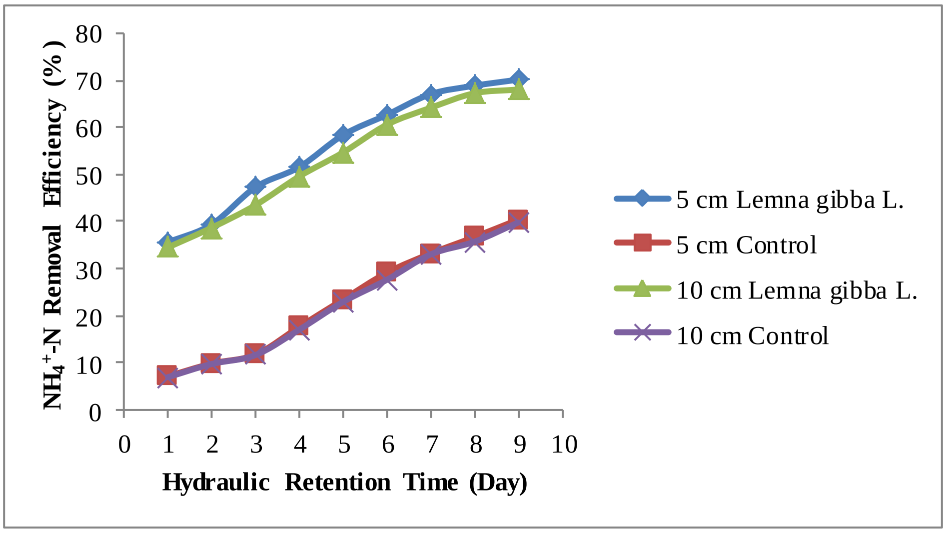

Fig 3. The NH_4^+-N removal efficiencies according to the various HRT and depths.

3.2 Nitrite Nitrogen (NO_2^--N)

NO_2^--N concentrations according to various HRT and depths were given in Figure 4. NO_2^--N concentrations decreased with the increase of HRT. NO_2^--N concentration in the planted reactor with a depth of 5 cm decreased from 15.0 (day 1) to 7.9 and 4.02 mg/l at days of 5 and 9, respectively. But the initial NO_2^--N concentration was 0.79 mg/l, therefore there was not any removal. This situtation showed that nitrification occured. The NO_2^--N concentrations in the planted and unplanted reactors which had a depth of 5 cm were 15.0 and 5.6, 7.9 and 3.9, 4.02 and 1.7 mg/l at days of 1, 5 and 9, respectively. The NO_2^--N concentrations in the planted and unplanted reactors which had a depth of 10 cm were 14.6 and 5.4, 7.2 and 3.7, 3.9 and 1.5 mg/l at days of 1, 5 and 9, respectively. As seen from Figure 4, although NO_2^--N concentrations were closed to each other in reactors with various depths, the concentrations were higher in reactors with 5 cm depth than the reactors with 10 cm depth.

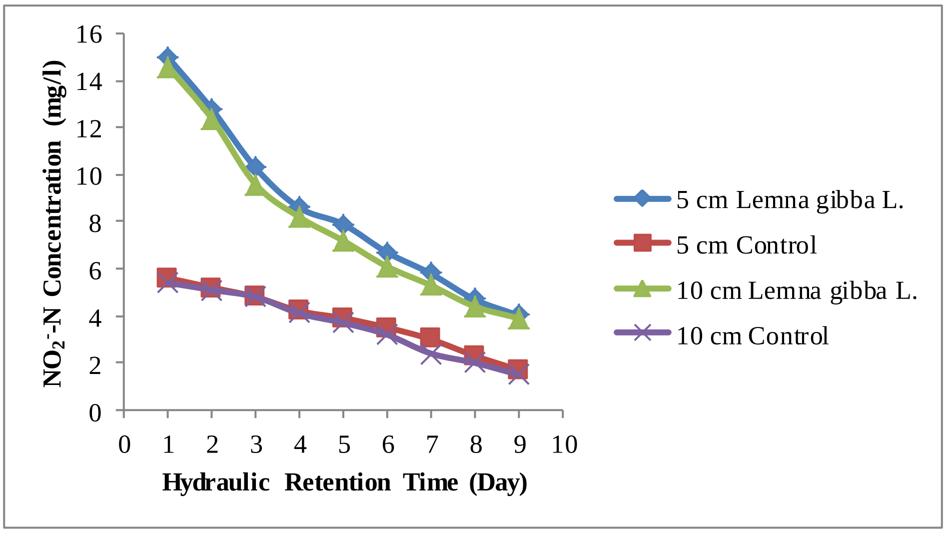

Fig 4. The NO_2^--N concentrations accaording to the various HRT and depths.

3.3 Nitrate Nitrogen (NO_3^--N)

The NO_3^--N concentrations according to various HRT and depths were given in Figure 5. The NO_3^--N concentrations decreased with the increase of HRT. The NO_3^--N removal was not seen in the planted reactors at day 9. Contrary, the NO_3^--N concentrations increased. The initial NO_3^--N concentration of 18.0 mg/l in the planted reactors with a depth of 5 cm increased to 125.2, 60.7 and 35.3 mg/l at days of 1, 5 and 9, respectively. There was an ammonium removal at the beginning and nitrite accured and the nitrite transported to the nitrate. The NO_3^--N concentrations in the unplanted reactors with a depth of 5 cm were 30.2, 15.7 and 5.2 mg/l at days of 1, 5 and 9, respectively. The NO_3^--N concentrations in the planted reactors with a depth of 10 cm were 124.0, 62.2 and 33.8 mg/l at days 1, 5 and 9, respectively. The NO_3^--N concentrations in the unplanted reactors with a depth of 10 cm were 28.8, 13.3 and 4.8 mg/l at day 1, 5 and 9, respectively. The various depths did not significantly effect the NO_3^--N concentrations. Higher effluent NO_3^--N concentrations than the influent values demonstrate the occurrence of nitrification. This situation showed that NH_4^+ transported to NO_3^- [23]. Organic nitrogen in the leachate transform by ammonification and nitrification reactions to oxidized forms (NO_2^- and NO_3^-) [24].

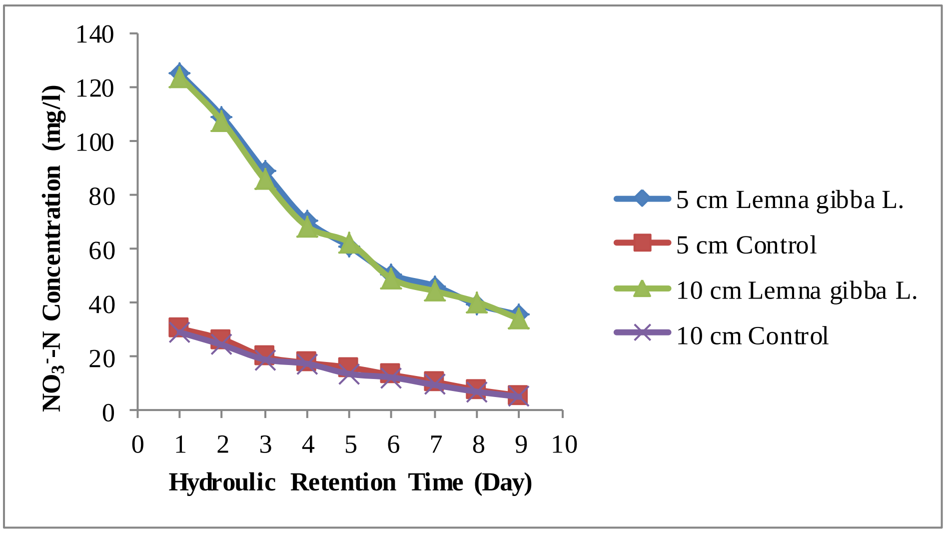

Fig 5. The NO_3^--N concentrations according to the various HRT and depths.

3.4 Ortophosphate (O-PO_4^{-3})

The maximum removal efficiency was determined as 32% in planted reactor (depth: 5 cm) at HRT of 9 days (Figure 6). The phosphate removal could be due to the adsorption, precipitation of microbial assimilation and plant uptake. The various HRT did not significantly effect removals. Removals in unplanted reactors (depth: 5 cm) were 15.0, 17.2 and 18.8% at days of 1, 5 and 9, respectively. Removals in planted and unplanted reactors (depth: 10 cm) were 21.2 and 14.6%, 24.2 and 16.8%, 27.2 and 18.2% at days of 1, 5 and 9, respectively. Depths were effected the removal efficiencies approximately at a percentage of 5%.

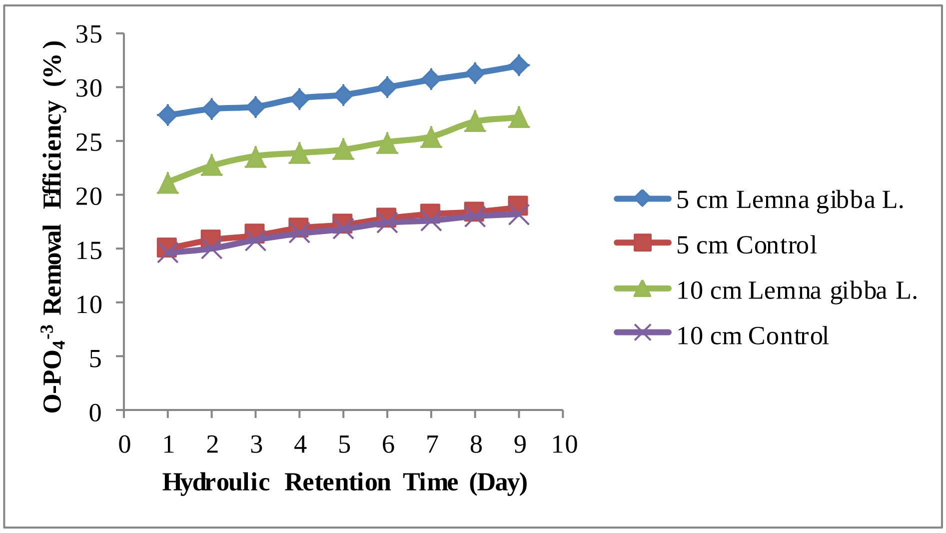

Fig 6. The O-PO_4^{-3} removal efficiencies according to the various HRT and depths.

3.5 Chemical Oxygen Demand (COD)

Removal efficiencies of COD according to the various HRT (1-9 days) and depths of the leachate (5 and 10 cm) were given in Figure 7. COD removal efficiency was 51.1 and 55.4% at day 9 (at the end of the study period) in the unplanted and planted reactor with a depth of 10 cm, respectively. COD removal efficiency was 58.0 and 52.0% at days 9 in the unplanted and planted reactor with a depth of 5 cm, respectively. As seen from Figure 7, the various depths did not significantly affect the COD removal efficiencies. *Lemna gibba* L. affected the removal approximately at a percentage of 3 due to various depths.

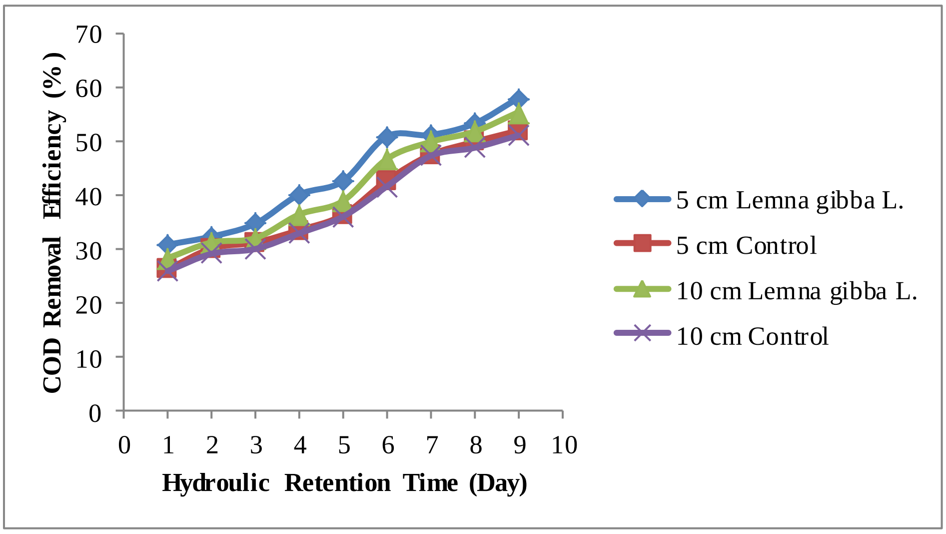

Fig 7. The COD removal efficiencies according to the various HRT and depths.

COD removal efficiencies (%) increased with the increase of HRT. The organic removal efficiencies increase with increasing time because the microorganisms had more time to degrade the organic materials [25]. Low removal rate for COD is because of the fact that microbial communities need longer retention times to break down the more recalcitrant material (tannings and lignins and scarcely biodegradable organics) in the leachate [23, 24, 26].

3.6 pH

The maximum pH (8.50) was seen in the planted reactor with a depth of 5 cm at day 9. pH variations according to the various HRT and depths were given in Figure 8.

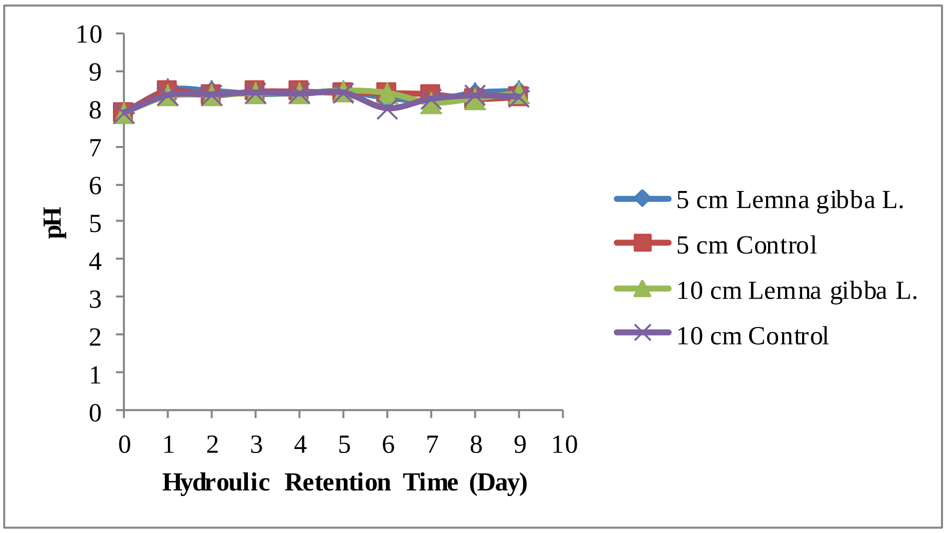

Fig 8. pH variations according to the various HRT and depths.

The various HRT and depths of the leachate did not affect the pH values of the leachate. As seen from Figure 8, in the planted and unplanted reactor with a depth of 5 cm, the initial pH value of 7.91 changed to 8.50 and 8.01, 8.47 and 8.04 and 8.48 and 8.04 at day 1, 5 and 9, respectively. In the planted and unplanted reactor with a depth of 10 cm initial pH value changed to 8.34 and 7.94, 8.49 and 7.97 and 8.42 and 8.01 at day 1, 5 and 9, respectively. pH values in the planted reactors were higher than those in the unplanted reactors. The increase in the pH values might be due to buffering capacity of the plants as a result of the photosynthetic activity of the planted reactors. Consumption of CO_2 by the duckweed reduces the amount of carbonic acid in wastewater which led to increase in the pH [25]. Photosynthetically active macrophytes generate oxygen and remove carbondioxide from the water, causing an increase in the water pH [26, 27].

3.7 Electrical Conductivity (EC)

The maximum EC value was determined as 8.04 mS/cm at day 9 in the planted reactor with a depth of 10 cm. The EC variations according to the various HRT and depths were given in Figure 9.

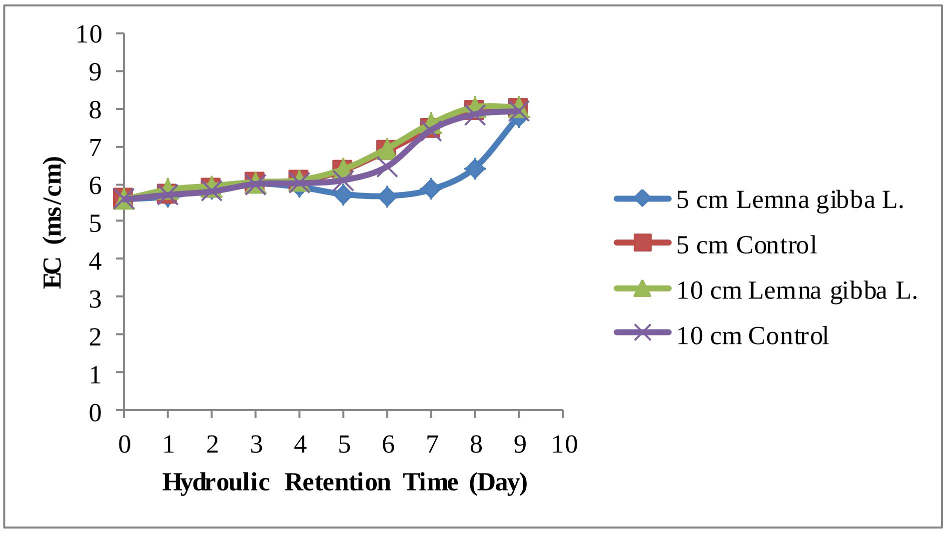

Fig 9. The EC values according to the various HRT and depths.

Various depths generally effected EC values. The depth of 10 cm caused higher EC values than the depth of 5 cm. The initial EC value of 5.59 mS/cm increased to 7.79 mS/cm and 7.99 mS/cm at day 9 in the planted and unplanted reactor with a depth of 5 cm, respectively. The initial EC value increased to 8.04 and 7.94 mS/cm at day 9 in the planted and unplanted reactor with a depth of 10 cm, respectively. EC values increased with the increase of HRT in the planted reactors.

4. Conclusion

Lemna gibba L. was selected in this study because of the rapid growth, high treatment potential, high accumulation capacity, tolerence to negative conditions low cost and to be found in the world. It was determined that *Lemna gibba* L. used in this study could remove the NH_4^+-N, O-PO_4^{-3} and COD from the leachate of the wild storage of Sivas city (Turkey). The maximum NH_4^+-N, O-PO_4^{-3} and COD removals seen in the planted reactors were 70.2%, 32.0% and 58%, respectively. It was also determined that nitrification occured. NO_2^--N and NO_3^--N concentrations increased at the final. This situation is an indicator of nitrification. pH of the leachate which had an initial value of 7.91 reached to a maximum of 8.50. Conductivity which had an initial value of 5.59 mS/cm reached to a maximum of 8.04 mS/cm.

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