THE ROLE OF DUCKWEED (*LEMNA MINOR L.*) IN SECONDARY CLARIFIER TANKS

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ABSTRACT

In this study, the effects of duckweed (*Lemna minor L.*) presence on the effluent water quality and settling characteristics in the secondary clarifier tank of a conventional biological treatment plant were investigated. For this purpose, the performances of the secondary clarifier with and without duckweed were compared. In the secondary clarifier tank with duckweed, COD, BOD_5, ammonium and phosphate removal efficiencies were higher by 15, 25, 35 and 45%, respectively. SS concentration of effluent and values of sludge volume index (SVI) were the same. The results showed that duckweed contributes to treatment efficiency of conventional biological treatment plant, which reduces the need of tertiary nutrients removal.

Keywords: Duckweed, wastewater, treatment, secondary clarifier.

SON ÇÖKELTME HAVUZLARINDA SU MERCİMEĞİNİN (*LEMNA MINOR L.*) ROLÜ

ÖZET

Bu çalışmada, bir klasik biyolojik atıksu arıtma tesisinin son çökeltme havuzunda oluşan su mercimeğinin çıkış suyu kalitesine ve çökelme karakteristiğine olan etkisi araştırılmıştır. Bu amaçla, su mercimeği bulunan son çökeltme havuzuyla su mercimeği bulunmayan son çökeltme havuzu karşılaştırılmıştır. Su mercimeği bulunan son çökeltme havuzunda; KOİ giderme verimi % 15, $BOİ_5$ giderme verimi % 25, amonyum giderme verimi % 35 ve fosfat giderme verimi % 45 daha yüksek bulunmuştur. Çıkış suyunun askıda katı maddesi ve çamur hacim indeksi (SVI) değerleri bakımından bir farklılık gözlenmemiştir. Bu sonuçlar, son çökeltme havuzunda oluşan su mercimeğinin arıtma verimini artıracağını ve üçüncül nutrient giderimi ihtiyacını azaltacağını göstermektedir.

Anahtar kelimler: Su mercimeği, atıksu, arıtma, son çökeltme havuzu.

I. INTRODUCTION

Duckweeds are small green floating plants of the Lemnaceae family. The family of Lemnaceae consists of four genera: *Lemna, Spirodella, Wolffia* and *Wolffiella* [1,2]. About forty species are identified worldwide [2,3]. Duckweeds grow at water temperatures between 5 and 35 ^oC with optimum growth between 20 and 31 ^oC depending on the specie [4]. Duckweed survives from pH 5 to 9, but grows best over the pH 6.5 to 7.5 range. When grown in nutrient rich waters, the protein content varies between 35 and 45 %. Fiber content is 10 to 15 % [5]. These values make the duckweed cost-effective, for recycling as fertilizer and animal fodder [6]. Duckweed growth is generally controlled by temperature and sunlight more than nutrient concentrations in the water. The moisture content of fresh duckweed is 94 to 95 % [7].

Excessive discharge of nutrients to the environment leads to eutrophication that in turn would promote the growth of blue green algae. This problem has become a matter of concern and advanced treatment processes have been developed to control nutrient discharges. These processes are effective but have high capital and operating costs. In the secondary clarifier of Elazığ Domestic Wastewater Treatment Plant, duckweed has been growing spontaneously. The hydraulic conditions and other factors (hydraulic retention time, initial nutrient concentrations, duckweed density, temperature and pH) may facilitate the duckweed growth, but the exact reasons may need a deep investigation. Although conventional biological treatment removes carbon, its nutrient removal is insufficient [8]. However, duckweed has the great capacity in absorbing the nutrients and their high nutrient removal efficiency can be used to clean wastewater in an effective, cheap and simple way.

Duckweed has been used for tertiary treatment of municipal and industrial wastewater for more than a decade [9]. But, the role of duckweed in the removal of organic material has been a subject of controversy. Indirect effects like provision of surface and substrate for bacterial growth and change of the physicochemical environment in the water as well as the possibility of direct removal of small organic compounds by heterotrophic growth were supposed [10]. Ammonia can be removed by duckweed uptake, nitrification-denitrification, ammonia stripping (at pH higher than eight) and algal and microbial assimilation [11]. Phosphorus removal can also be attributed to duckweed uptake, microbial assimilation, precipitation with cations and adsorption on clay and organic matter [11].

In this context, this study aims at investigating the effect of duckweed presence in secondary clarifier on the effluent water quality and settling characteristics. For this purpose, the performances of secondary clarifiers with and without duckweed were compared.

II. MATERIALS AND METHODS

Elazığ Domestic Wastewater Treatment Plant has four secondary clarifiers with the diameter of 34 m. The base slope of the clarifiers is 1/15. The weir length is 107 m.

The wastewater characteristics entering secondary settling are given in Table 1.

Table 1. The average wastewater characteristics entering secondary settling (with standard deviations)

Parameter	Concentration
COD, mg/l	260±11
BOD_5, mg/l	175±3
Ammonium, mg/l	11.5±0.7
Nitrate, mg/l	0.2±0.2
Phosphate, mg/l	9±0.3
pH	7.3±0.1
SS, mg/l	140±6
Temperature, ^{o}C	21±0.1

The experimental study lasted for 7 days without harvesting. The death of duckweed did not observe throughout experiment. All experiments repeated two times and averages are reported.

COD, phosphate and SS analyses were performed according to Standard Methods [12]. SS concentration was determined using Whatman GF/C filters. Ammonium and nitrate concentration was measured by Standard Kit (Merck Specquorant). BOD_5 analysis was made by Lovibond model apparatus.

III. RESULTS AND DISCUSSION

The secondary settling tanks allow the microorganisms and other solids to settle after biological treatment. COD and nutrient removal in secondary settling tanks are generally minimal.

Average effluent concentrations during the experimental period are shown in Table 2. COD removal efficiency in secondary settling tank with and without duckweed was found as 20 and 5 %, respectively. Hence, COD removal was 15 % higher in the presence of duckweed. It was reported that degradation of organic material was enhanced by duckweed through both additional oxygen supply and additional surface for bacterial growth [10].

Table 2. Average effluent concentrations (with standard deviations)

Parameter	Effluent concentrations	
	With duckweed	Without duckweed
COD, mg/l	208±10	247±2
BOD_5, mg/l	79±4	123±4
Ammonium, mg/l	7.5±0.4	11.3±0.5
Nitrate, mg/l	-	-
Phosphate, mg/l	5±0.4	8.9±0.2
pH	7.8±0.1	7.8±0.1
SS, mg/l	50±6	50±6
Temperature, ^{o}C	21±0.1	21±0.1

The BOD_5 is degraded by microbial population associated with the plant's roots, suspended in the water column and present in the sediment. BOD_5 removal efficiency was about 55 % in secondary settling tank with duckweed and 30 % in secondary settling tank without duckweed. Comparing of both tanks shows an average increase by 25 % with duckweed.

The main removal mechanisms of N are nitrification/denitrification, duckweed uptake and harvesting [10,13,14]. Significantly higher ammonium removal efficiency in secondary settling tank with duckweed (35%) was observed compared to that without duckweed (about 0 %).

Duckweed prefers ammonium to nitrate [11]. Nitrate concentration was lower than 0.5 mg/l in influent of secondary settling tank. Therefore, the effect of duckweed formation on nitrate removal couldn't observe.

Phosphate removal in secondary settling tank with duckweed was 45%. However, phosphate removal in secondary settling tank without duckweed was negligible. The direct contribution of duckweed to P removal can vary between 9 % and % 61[13,14,15]. The phosphate removal obtained in this study is in accordance with these reported values.

The standard deviation of results for COD, BOD_5, ammonium and phosphorus are 4.08, 2.16, 3.41 and 3.56 %, respectively.

The pH values were measured as 7.8 in effluent of both secondary settling tanks. These results show that duckweed did not change pH value of effluent water.

SS removal with duckweed could be attributed to the duckweed cover, which prevented algal growth as well as providing the quiescent condition in the unit for the proper sedimentation of the SS. Furthermore, the duckweed roots act as a filter media where SS would attach and helped to remove some part of the SS [16]. SVI is an indication of the sludge settleability in the secondary clarifier. SVI is a useful test that indicates changes in the sludge settling characteristics and quality. Effluent SS concentrations and SVI values in both clarifiers did not differ significantly and averaged 50 mg/l and 100-150 ml/g, respectively. Other researchers reported that SS removal was higher in the duckweed-based wastewater treatment systems than in waste stabilizations ponds [16] and algae-based ponds [17]. Our results are inconsistent with that of these researchers. We can suggest that SS removal was primarily by sedimentation and was not increase by duckweed further.

IV. CONCLUSIONS

In the secondary clarifier tank with duckweed, the COD, BOD_5, ammonium and phosphate removal efficiencies were significantly higher compared to that without duckweed presence. Hence the presence of duckweed on secondary clarifier will improve system performance and decrease the nutrient load to receiving body. Hence, the formation of duckweed will decrease the cost of tertiary nutrient removal.

Effluent SS concentrations and SVI values in both clarifiers did not differ significantly. Hence, duckweed formation in the secondary clarifier did not adversely affect the settling characteristics of the sludge.

Also, the conditions improving the duckweed formation needs further investigations.

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