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Hybrid Aquatic System for Treatment of Domestic Wastewater Containing Pharmaceutical Residuals

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Abstract

This experimental research aimed to study the efficiencies of wastewater treatment and reducing pharmaceutical residuals by a hybrid aquatic system. Four laboratory-scale reactors, each filled duckweeds of 0.63 kg/m^2, were operated at the organic loading rate (OLR) of 12-50 kg COD/(ha-day) and illuminated with red LED at the light intensity of 150 µmol/(m^2-sec). Three reactors, each filled with plastic media at the specific area of 50 m^2/m^3, were fed with domestic wastewater at the hydraulic retention times (HRTs) of 5, 10 and 20 days; the fourth reactor was operated at the HRT of 10 days, but without plastic media. The experimental results showed the COD removal efficiency of 36.11, 40.74 and 76.85% at HRTs of 5, 10 and 20 days, respectively; while the reactor without plastic media had less COD removal efficiency. The hybrid aquatic system was also effective in removing sulfamethoxazole, a common anti-biotic drug, from the influent wastewater about 99%.

Keywords : hybrid aquatic system; domestic wastewater; pharmaceutical residuals; sulfamethoxazole; red LED

Introduction

Most Thai people usually consume antibiotic drugs for curing diseases and health protection. The residues antibiotic drugs will eventually be released together with domestic wastewater and can reach water sources, thus contaminating the ecosystem and food chain [1]. The hybrid aquatic system utilizes natural processes to treat wastewater and does not require complicated operation procedures. It involves aquatic plants to perform photosynthesis which produces oxygen for heterotrophic bacteria to decrease organic matters. These aquatic plants could also absorb nutrients (nitrogen (N) and phosphorus (P)) from the wastewater which help to purify the treated effluent. Duckweeds are a common aquatic plant in the tropics and have been employed for wastewater treatment [2, 3]. The objectives of this study were: (1) to investigate the efficiencies the hybrid aquatic system incorporating duckweed and plastic media in treating a domestic wastewater, (2) to compare the efficiencies of the hybrid aquatic system equipped with red LED light and without red LED light, and (3) to investigate the efficiencies of the hybrid aquatic system in removing a common antibiotic drug (Sulfamethoxazole) [4].

Materials and Methods

Laboratory-scale reactors

Four laboratory-scale reactors, each with a size of 20×40×30 cm^3 (width × length × depth), were constructed at the Civil Engineering laboratory, Faculty of Engineering, Thammasat University, Rangsit Campus, Pathumthani province, Thailand (Figure 1). Three reactors were equipped with plastic media, each at the density of 50 m^2/m^3 (Figure 2) and duckweeds at the density of 0.63 kg/m^2. The last laboratory-scale reactor without plastic media was used as the control.

Experimental conditions

1) The three laboratory-scale reactors were operated at the hydraulic retention times (HRT) of 5, 10 and 20 days, corresponding to the organic loading rates (OLR) of 12-50 kgCOD/(ha-day). The control laboratory-scale reactor was operated at the HRT of 10 days. Experimental data obtained from this phase were used to determine the k_T value of COD removal by the hybrid aquatic system.

2) The effects of red LED light on the wastewater treatment efficiencies of the hybrid aquatic system were investigated by operating a laboratory-scale reactor at the HRT of 10 days and equipped with red LED light (Figure 3) at the light density of 150 μmole/m^2-sec which was previously found to be optimum for algal growth [5] (Figure 4). Another laboratory-scale reactor was operated at the HRT of 10 days, but without red LED light for comparing the treatment efficiencies.

3) The efficiency of the hybrid aquatic system in removing Sulfamethoxazole was investigated by feeding this antibiotic drug at the concentration of 35.60 μg/l to a laboratory-scale reactor equipped with red LED light and operated at the average HRT of 10 days. Three effluent samples were collected after 7 days of operation for determination of the Sulfamethoxazole concentration using LC-MS/MS technique at the department of Civil and Environmental Engineering, Mahidol University, Nakhon Pathom, Thailand in which the relative standard deviation was found to be 6.28% [6]. In addition, there effluent samples were examined for the presence of algal and protozoa species by a microscope at 10-40x.

Figure 1 Laboratory-scale reactors

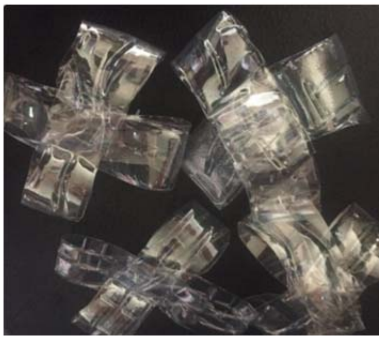

Figure 2 Plastic media

Figure 3 Laboratory-scale reactors with red LED light

Figure 4 PAR Meter, Apogee, USA

Results and Discussion

Treatment efficiencies

The experimental results of the four laboratory-scale reactors are show in Table 1. The COD removal efficiencies of 36.11, 40.74 and 76.85% were found at the HRTs of 5, 10 and 20 days, corresponding to the effluent COD (filtered) concentrations of 70, 65 and 25 mg/l, respectively. The laboratory-scale reactors with the plastic media were very effective in removing SS and TKN with the effluent concentrations of below 10 mg/l and non-detectable, respectively. The control laboratory-scale reactor without plastic media apparently showed inferior treatment effciencies in which the effluent COD, SS, Coliform bacteria and TKN concentrations were higher than the laboratory-scale reactor operating at the same HRT of 10 days, suggesting the benefits of plastic media which had attached-growth microorganisms in wastewater treatment. The hybrid aquatic system operating at the HRT of 10 days was considered to be appropriate for domestic wastewater treatment because its effluent concentrations could meet the standards for discharge or reuse [7].

Table 1 Wastewater treatment efficiencies

Parameters	Influent concentrations	Effluent concentrations		
		HRT = 5 days	HRT = 10 days	HRT = 20 days
COD, filtered, mg/l	110±15	70±16	65±36 (75)*	25±6
SS, mg/l	22±18	8±1	6±3 (35)*	5±6
Coliform bacteria, CFU100/ml	3.51×10^{6}	3.19×10^{6}	9.84×10^{5} (1.30×10^{6})*	2.46×10^{5}
TKN, mgN/l	6	ND	ND (2)*	ND

( )* = Average water quality from reactor without plastic media

ND = non-detectable

Table 2 Wet weight of duckweeds

Parameters	Effluent concentrations		
	HRT = 5 days	HRT = 10 days	HRT = 20 days
Wet Weight of duckweeds before treatment, kg/m^2	0.63	0.63 (0.63)*	0.63
Wet Weight of duckweeds After treatment, kg/m^2	0.70	0.65 (0.73)*	0.60

( )* = Wet weight of duckweed in reactor without plastic media

Table 2 shows the wet weights of duckweeds at the begining and after 30 days of experiments which indicated some increases espectially at the HRT of 5 days because of more nutrients inputs. The reactor without plastic media operating at the HRT of 10 days had higher duckweed growth than that without plastic media, probably because there were no attached-growth microorganisms to compete for their growth. These duckweeds could be harvested for reuses as animal feeds or as a raw marterial for composting [8].

By assuming plug flow conditions in the laboratory-scale reactors, the first-order kinetic value (k_T) for COD removal could be determined from equations (1) and (2) as follow :

$$\frac{C_e}{C_o} = e^{-k_T t} \quad (1)$$

$$k_T = k_{20}\,(1.06)^{T-20} \quad (2)$$

when

C_0 = Influent COD concentration, mg/l

C_e = Effluent COD concentration, mg/l

t = hydraulic retention time, days

k_T = kinetic coefficient at temperature T, day^{-1}

k_{20} = kinetic coefficient temperature at 20 °C

T = liquid temperature, °C

From the data of Table 1 in which the liquid temperature was 30 °C, the k_{30} was found to be 0.071 day^{-1} and the k_{20} was found to be 0.040 day^{-1}. These k values can be used for design and operation of a hybrid aquatic system to achieve the desired effluent COD concentration.

Effects of red LED light

Table 3 shows the wastewater treatment efficiencies of the 2 laboratory-scale reactors operating at the HRT of 10 days, one with red LED light and the other wiyhout. It can be seen that the effluent concentrations of the laboratory-scale reactor with red LED light were lower than those of the one without red LED light. These results suggest the benefits of red LED light in wastewater treatment by the hybrid aquatic system probably due to increased photosysthetic reactions which supported the algal-bacterial synthesis. In areas with limited space, the hybrid aquatic system equipped with red LED light could therefore be constructed indoor for wastewater treatment with high efficiencies.

Table 3 Wastewater treatment efficiencies with and without red LED light

Parameters	Influent concentrations	Effluent concentrations
COD, filtered, mg/l	164±41	48±6 (74±9)*
SS, mg/l	31±4	11±4 (19±5)*
Coliform bacteria, CFU100/ml	6.50×10^{4}	3.30×10^{4} (4.30×10^{4})*
TKN, mgN/l	5.6	ND (ND)*

( )* = Average water quality from reactor without red LED light

Efficiency of Sulfamethoxazole removal

A laboratory-scale reactor with plastic media and red LED lighting at 150 μmole/m^2-sec was operated at the HRT of 10 days and continuously fed with Sulfamethoxazole at the concentration of 35.60 μg/l. Three effluent samples were analyzed for the Sulfamethoxazole concentrations which showed the average value to be 0.02 μg/l (Table 4). This result suggested the effectiveness of the hybrid aquatic system in removing Sulfamethoxazole from domestic wastewater, probably through such mechanisms as biodegradation, plant uptake, absorbtion and sedimentation, further reseach in this area is suggested. Because antibiotic drug contemination of water resources is becoming more serious [4], the application of the hybrid aquatic system in removing these antibiotic drugs is highly strongly recommended (Figures 5-7) represent major algal species while (Figures 8-10) are the major protozoa species found in the hybrid aquatic system. These results suggest the diversity of mixed algal and protozoa species in the hybrid aquatic system which helped to support the algal-bacterial synthetic reactions respondsible for wastewater treatment including Sulfamethoxazole degradation.

Table 4 Sulfamethoxazole concentrations

Parameters	Influent concentrations	Effluent concentrations
Sulfamethoxazole concentrations,μ g/l	35.60±2.24	0.02±0.01

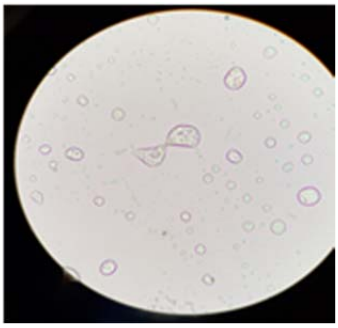

Figure 5 *Sphaerocystis sp.*

Figure 6 *Mougeotia sp.*

Figure 7 *Navicula sp.*

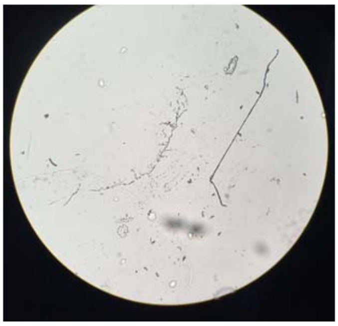

Figure 8 *Paramecium sp.*

Figure 9 *Euglena tripteris*

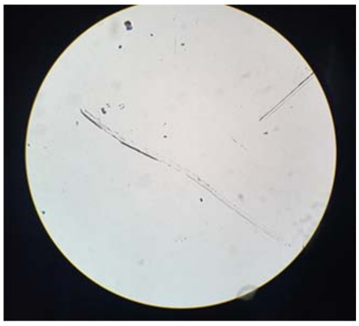

Figure 10 *Tintinnopsis radix*

Conclusions

Based on the experimental results of this study, the following conclusions are made:

1. The hybrid aquatic system was found to be effective in domestic wastewater treatment in which the treated effluent characteristics could meet the discharge standards when operated at the HRT of 10 days.

2. The k_{20} of the hybrid aquatic system was found to be 0.040 day^{-1}, applicable for system design and operation.

3. The hybrid aquatic system equipped with red LED light was found to be more effective in wastewater treatment than that without, suggesting its applicability for construction and operation indoor in areas with limited space.

4. The hybrid aquatic system with red LED light was found to be very effective in removing Sulfamethoxazole more than 99% from the influent wastewater.

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