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POTENTIAL OF *Epipremnum aureum* IN REDUCTION OF CHEMICAL OXYGEN DEMAND IN WASTEWATER

(Potensi *Epipremnum aureum* dalam Pengurangan Permintaan Oksigen Kimia dalam Air Sisa Buangan)

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Abstract

High chemical oxygen demand (COD) levels in water indicate a vast amount of oxidizable matter that consumes a lot of dissolved oxygen in water. This has an adverse impact on both aquatic ecosystems and human health. Wastewater from the fish cracker industry typically has high organic content and high COD value. This study focuses on the potential of *Epipremnum aureum* as a new plant for reducing COD in fish cracker industry wastewater. Due to its relative abundance and cost-effectiveness, *Epipremnum aureum (E. aureum)* was selected as a phytoremediation plant. The parameters affecting COD reduction, such as pH of wastewater, retention time, initial COD concentration, and plant number used in phytoremediation were investigated. After ten days of retention time with two *E. aureum* plants, the highest COD reduction was 99.42% in pH 6 of 75% wastewater. *E. aureum* produced new shoots in 50% (v/v) wastewater concentration after 14 days of retention time, indicating that the plant is suitable for planting in polluted water or industrial effluent. Therefore, *E. aureum* can be categorized as a pollution resistance plant. This study proves that *E. aureum* can be utilized as an alternative method for COD reduction in wastewater.

Keywords: chemical oxygen demand, phytoremediation, *Epipremnum aureum*

Abstrak

Tahap permintaan oksigen kimia tinggi (COD) dalam air menunjukkan sebahagian besar bahan teroksida yang menggunakan banyak oksigen terlarut di dalam air. Ini mengakibatkan kesan buruk terhadap ekosistem akuatik dan kesihatan manusia. Air sisa dari industri keropok ikan biasanya mempunyai kandungan organik yang tinggi dan nilai COD yang tinggi. Kajian ini memberi tumpuan kepada potensi *Epipremnum aureum* sebagai pokok baharu untuk pengurangan COD dalam air sisa industri keropok ikan. *Epipremnum aureum (E. aureum)* dipilih sebagai pokok untuk fitoremediasi kerana ianya banyak dan menjimatkan. Parameter yang mempengaruhi pengurangan COD seperti pH air buangan, masa hubungan, kepekatan awal COD dan jumlah pokok yang digunakan dalam fitoremediasi telah diselidik. Selepas sepuluh hari masa hubungan menggunakan dua pokok *E. aureum*, penurunan COD tertinggi adalah 99.42% pada pH 6 dalam 75% air sisa. *E. aureum* menghasilkan pucuk baru dalam air sisa pada kepekatan 50% setelah 14 hari masa hubungan, menunjukkan bahawa pokok itu sesuai untuk ditanam dalam air tercemar atau air buangan industri. Oleh itu, *E. aureum* boleh dikategorikan sebagai pokok yang ada ketahanan pencemaran. Berdasarkan kajian ini, *E. aureum* terbukti menjadi kaedah alternatif untuk pengurangan COD dalam air sisa.

Kata kunci: permintaan oksigen kimia, fitoremediasi, *Epipremnum aureum*

Introduction

Chemical oxygen demand (COD) is a chemical method for determining the amounts of reductive substances oxidized in water samples [1]. In studies investigating the operation and management of wastewater treatment plants and the properties of river pollution and industrial wastewater, rapid determination of organic pollution parameters, often expressed as symbolic COD, is important. The high COD level indicates a greater amount of oxidizable organic material in the sample, which causes dissolved oxygen (DO) levels to decrease. Wastewater from the fish cracker industry contains a high concentration of COD [2]. Hence, COD should be reduced, and phytoremediation is one inexpensive treatment method to achieve this end. Phytoremediation is the method that uses plants to treat contaminated soils, sludge, sediments, surface water and groundwater. The plants transfer, contain, or convert pollutants to ensure environmental safety [3]. The medium of phytoremediation is usually soil and water bodies that are contaminated by heavy metals, inorganic matter, radioactive elements, or organic matter [4]. Through several phytoremediation, the pollutants can be purified [5].

Epipremnum aureum (E. aureum) can be used in phytoremediation. It is a plant that belongs to the genus Kirin leaf, a large evergreen vine that grows in the tropics. They often climb rocks and tree trunks with well-developed roots, and they can be grown hydroponically. Because of the tenacious vitality*, E.* aureum can grow well whether it is planted in pot or hydroponics grown by just a few stalks. [6] investigated the performance and stratified microbial community of *E. aureum*-affected vermi-filters during the recycling of concentrated excess sludge. *E. aureum* has also been investigated as a cathode candidate in microbial fuel cells for wastewater treatment [7]. In this study, the use of *E. aureum* for treating industrial wastewater was investigated. The ability of the plants to reduce the COD rates according to several parameters, such as plant number, initial concentration of water samples, and pH of the water sample, were studied as independent variables.

Materials and Methods

Materials

A one-year-old *Epipremnum aureum (E. aureum)* plant was collected from a Taiping, Perak nursery. All the plants were ensured to have 30 cm and the same quantity of leaves by cutting down extra stems and leaves. All chemicals used were analytical grade.

Industrial wastewater characterization

A wastewater sample was collected from a local, small, and medium enterprise (SME) that processes fish crackers, located in Tumpat, Kelantan. Wastewater in-situ analysis, i.e., temperature, total dissolved solids, pH, salinity, and dissolved oxygen (DO) were analysed using an YSI Multiparameter. Wastewater samples were collected twice, and all samples were assessed in duplicates.

Hydroponic ability and pollution resistance of *E. aureum*

E. aureum was placed in a beaker filled with distilled water for one week until the plants adapted to the aquatic environment and showed an increase of leaves and the growth of hydroponic roots. The leaves were counted, and plant length was measured using a ruler. Plants that are adapted to the water-based environment were transferred into the beaker filled with 500 mL of a 50% (v/v) wastewater sample for 2 weeks without additional nutrient supplementation. A similar experiment was set up with 500 ml of distilled water as a control.

Effect of initial pH of the wastewater in COD reduction

The concentration of the wastewater was fixed at 10% (v/v) concentration with a volume of 500 mL. The initial water pH was adjusted to pH 5, 6, 7, and 8 using H_2SO_4 and NaOH in a separate beaker. One *E. aureum* was planted in beakers filled with wastewater with pH 5, 6, 7, and 8 respectively for 1 week. The COD reduction was determined after one week. A control experiment was conducted using the same procedure but without the *E. aureum* plant.

Effect of the initial concentration of the wastewater in COD reduction

One *E. aureum* was planted in separate beakers filled with 500 mL wastewater of 10%, 25%, 50%, and 75% (v/v). The wastewater was adjusted to the optimum pH 6, which was obtained from the previous experiment. The COD reduction was determined after one week. A control experiment was conducted using the same procedure but without the *E. aureum* plant.

Effect of contact time and number of plants in COD reduction

The optimum concentration of the wastewater was set at 75% (v/v) which was obtained from the previous experiment. The wastewater was adjusted to an optimum pH 6. Beakers containing 500 mL of 75% (v/v) water were planted separately with 1 and 2 plants. The COD reduction was determined from day 4 until day 14. A control experiment was conducted using the same procedure but without the *E. aureum* plant.

Determination of COD reduction

The COD concentration for the wastewater was carried out using the HACH Method 8000 and USEPA Reactor Digestion Method (HR) with a DR 6000 Spectrophotometer. The percentage reduction of the COD was calculated using Eq. 1.

$$COD\ reduction\ (\%) = \frac{\text{Initial COD concentration} - \text{Final COD concentration}}{Initial\ COD\ \text{concentration}}\ x\ 100\% \tag{1}$$

Results and Discussion

Water quality of wastewater

Table 1 shows the results for each parameter via *in-situ* and *ex-situ* analysis of wastewater collected for first and second sampling. The readings of COD for both were 916 mg/L of COD for the first water sampling and 1792 mg/L for the second water sampling, which far exceeded the effluent standard B (EQA 1974). High COD levels in fish cracker wastewater were also reported by [2] and [8]. The water sample in the second sampling was discharged fresh from the process, hence the higher COD concentration. The COD decreases with increasing time because the bacteria in the water will grow and degrade the organic matter in the water sample [9].

Hydroponic ability and pollution resistance of *E. aureum*

Figure 1 shows the hydroponic roots of *E. aureum* in water. There were new roots that grew after 7 days in the distilled water indicating that the plant was suitable to plant in a water based medium (Figure 1b). It showed that the plant could grow and reproduce in a water-based medium. In other words, the plant had hydroponic ability. Figure 1c shows that there were new shoots that grew from the plant after 14 days in the 50% (v/v) wastewater. This indicated that the plant is suitable to be planted in polluted water or industrial effluent.

There were some rotten shoots in Figure 1c, yet there were also new shoots growing although it took a longer time (two weeks). This indicates that the plant had pollution resistance towards pollutants [10].

COD reduction based on different pH of wastewater

The data presented in Figure 2 indicates that the optimal pH for COD reduction by *E aureum* is pH 6. The average COD reduction of wastewater with *E aureum* increased from pH 5 to pH 6. After reaching the highest reduction of 89.72% at pH 6, COD reduction decreased from pH 7 to pH 8 because *E. aureum* performs better remediation in pH 6 water. The presence of plants in wastewater can deplete dissolved CO_2 during a period of high photosynthetic activity. The photosynthetic activity increases the dissolved oxygen in water creating aerobic conditions in wastewater which favours aerobic bacterial activity which reduces BOD and COD [11].

Based on this descriptive result, pH 6 was chosen for the subsequent experiment because it yielded the highest COD reduction. In addition, pH 6 was the optimum pH for reaching a well-tolerated phytoremediation process by *E. aureum* [12]. Therefore, *E. aureum* is suitable for being planted in a slightly acidic medium. This result has also been statistically tested using a one-way analysis of variance (ANOVA) as summarised in Table 2. Table 2 shows that there were no significant differences in COD reduction between pH 5, pH 6, pH 7, and pH 8. Therefore, any pH value can be chosen for subsequent experiments. In this case, however, pH6 was chosen since Figure 2 showed that it had the highest COD reduction.

Table 1. Water quality of fish cracker's wastewater

Physio-Chemical Parameter	**1st Sampling**	**2nd Sampling**	**EQA Standard B**
DO (%)	11.6	4.0	-
pH	4.88	5.45	5.5-9.0
COD (mg/L)	916	1792	200
TDS (mg/L)	903.5	491.9	-
Temperature (˚C)	28.52	30.14	40

- Not available

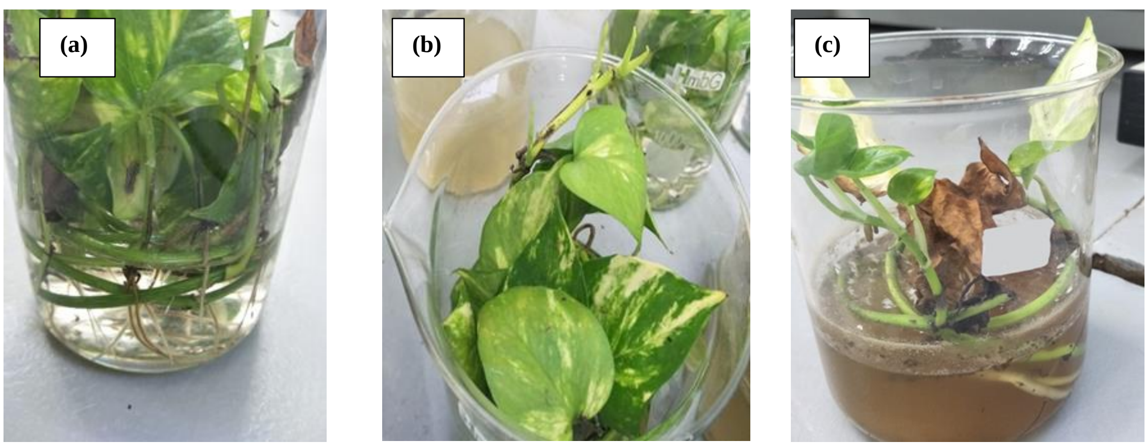

Figure 1. The hydroponic roots of the *E. aureum:* (a) After transfer from soil to water (Day 0) (b) After 7 days grew in distilled water (c) After 14 days grew in 50% wastewater

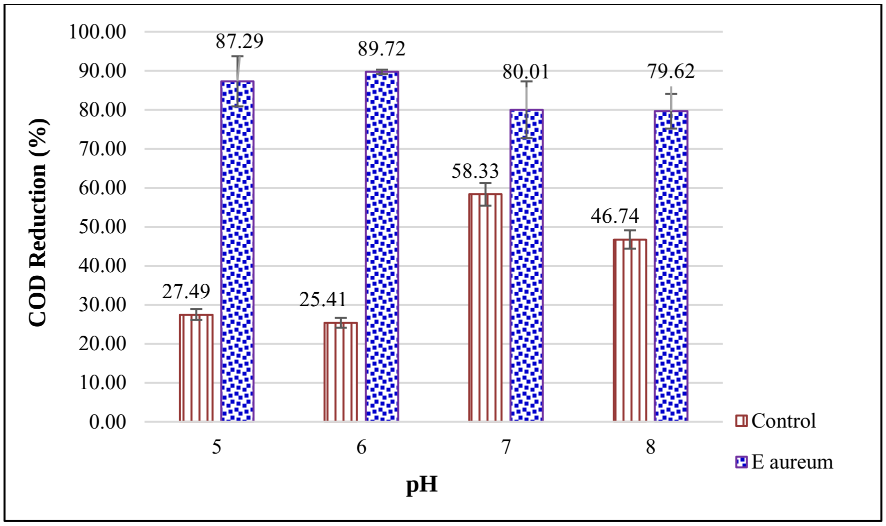

Figure 2. Effect of pH of wastewater on the COD removal percentage (%)

Table 2. The one-way ANOVA for different groups of pH

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups of pH	157.144	3	52.381	1.831	0.282
Within Groups of pH	114.445	4	28.611		
Total	271.589	7			

COD reduction based on different concentrations of wastewater

Figure 3 indicates that the average COD reduction from the *E. aureum* plant increased from 10% (v/v) to 75% (v/v), after reaching the highest removal of 91.57% at 75% (v/v) wastewater concentration. The average reduction of COD decreased to 73.43% in 100% (v/v) wastewater concentration. As the wastewater concentration increased, the organic compounds increased, hence providing more nutrients for the plants to grow and conduct phytoremediation. When 100% (v/v) wastewater concentration was used, the plant failed to adapt to this level of pollutant concentration, hence the COD reduction percentage decreased [13]. Study [14] shows that the increase of salt content in sewage, the plant height, above ground and underground biomass, total biomass, leaf length, leaf width and leaf area of the plants were decreased. As a result, the root-shoot ratio was significantly increased, and the degree of inhibition above ground was greater than that of the root system, indicating that the sensitivity of the root system to wastewater was lower than that of stems and leaves. Therefore, the roots of *E. aureum* cannot adapt to the wastewater with 100% (v/v) concentration.

The one-way analysis of variance (ANOVA) for different groups of wastewater concentration has been tabulated in Table 3. The result shows that there are significant mean differences in the COD reduction percentage in concentrations of wastewater from 10% (v/v) to 100% (v/v). This result statistically supports the descriptive result visualised in Figure 3, where 75% (v/v) wastewater concentration is the optimum level.

COD reduction based on contact time and the number of plants

Figure 4 shows the effect of plant number and contact time on wastewater COD reduction. In this study, treatment with 2 plants had a higher COD removal percentage relative to treatment with 1 plant because the phytoremediation rate was doubled. Thus, the more *E. aureum* plants in the same medium, the more efficient the COD removal in the water sample. In the study by [15], a second addition of plant was used after completed the first batch, and an increase in uptake of 96.7 percent was observed, compared to the result obtained in this study, which is 95.78 percent after 7 days of treatment using 2 plants. Therefore, the addition of several plants will cause a COD removal percentage to be greater than 95%, which is very satisfying. The difference in COD removal percentage between 1 plant treatment and 2 plant treatments was quite small, at 4.25 percent. Thus, for dealing with the industrial and commercial factors of effluent treatment, a one plant treatment was preferred because more wastewaters can be treated at one time with a smaller number of plants thereby reducing the cost of planting the plants.

With increasing contact time, the percentage of COD reduction is also increased. The COD reduction percentage increased gradually but it decreased after day 14. This showed that the lifetime of the *E. aureum* plant in treated sample water was only from day 7 to day 10. After 14 days of contact with 75% (v/v) of wastewater, the plants started to rot thereby decreasing COD reduction percentage. In this case, 2 plants were better than the 1 plant treatment because when the plants started to rot, there would be longer stems, more roots, and more leaves to conduct phytoremediation [16]. Therefore, the more *E. aureum* plants in the same medium, the more efficient the COD removal from the water sample because the phytoremediation rate was doubled.

To support the descriptive result in Figure 4, two-way analysis of variance (ANOVA) was done, and the result is summarised in Table 4. This analysis was chosen due to two factors, namely, the different number of plants and varied contact times, were considered simultaneously in investigating COD reduction percentage in 75% (v/v) wastewater concentration. The result showed a significant difference only existed in contact time but not in the plant number. Therefore, it can be concluded that contact time influences the COD reduction percentage in wastewater regardless of the number plants in the water. Furthermore, the turkey test in Table 5 shows that a different mean exists in the contact time of 4 days than it does at 10 days which is highlighted in Table 5.

The change in concentration with time can be expressed using rate laws. Figure 5 depicts the kinetic data of COD concentration (mg/L) reduction plotted against the first and second-order reactions. Only the plot of Figure 5a is linear with a high coefficient of determination (R^2) of 0.952, while other models (Figure 5b) have poor fits. Thus, the reaction obeys a first-order reaction rate law in which rate k was 0.5248 $mgL^{-1}.day^{-1}$. In this regard, the kinetics study of COD reduction from fish cracker wastewater using *E aureum* exhibited that the reduction process in this study followed the reaction trend of the first-order kinetic model. The concentration of COD decreases with the increasing contact time.

This finding converges previous studies by Musa et al. [17] which used locoweed and sunflower as the phytoremediation plants. The results reveal that phytoremediation is a first-order process by which rates are directly proportional to the substrate concentration driving force. Phytoremediation enhances the rate of the bioremediation process by reducing the ultimate substrate concentration achievable through bioremediation alone, though the first-order rate constant is reduced in the process. Plant microbes also contributed to the phytoremediation process. However, the mechanism of phytoremediation by *E. aureum* is still unknown and requires extensive research.

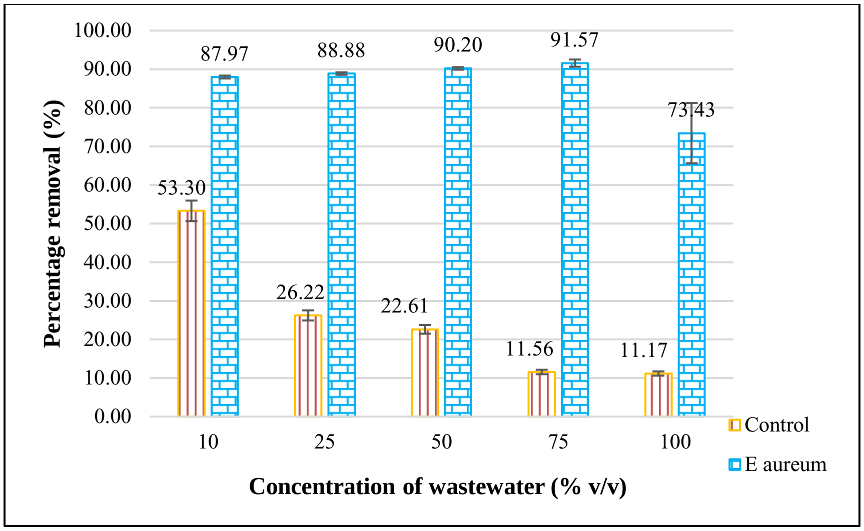

Figure 3. Effect of different concentrations of wastewater to reduce COD

Table 3. The one-way ANOVA for different groups of wastewater concentrations

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups of wastewater concentration	435.597	4	108.899	8.773	0.018
Within Groups % wastewater concentration	62.068	5	12.414		
Total	497.665	9			

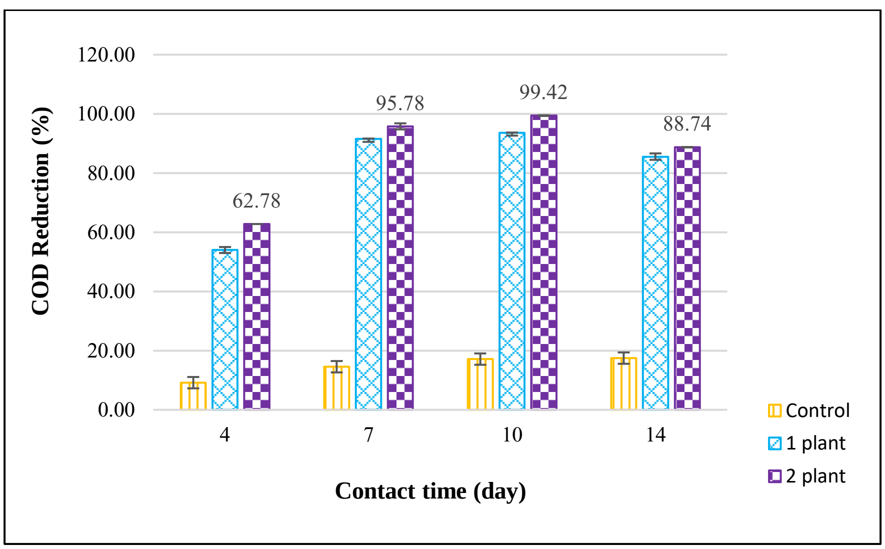

Figure 4. Effect of number of plant and different contact times of treatment on wastewater

Table 4. Two-way ANOVA for different groups of contact time and number of plants

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1769.868[a]	3	589.956	3.473	0.051
Intercept	112672.671	1	112672.671	663.304	0.000
Plant	.000	0	.	.	.
Time	1435.070	2	717.535	4.224	0.041
Plant * Time	.000	0	.	.	.
Error	2038.390	12	169.866		
Total	116480.928	16			
Corrected Total	3808.258	15			

a. R Squared = .465 (Adjusted R Squared = .331)

Table 5. Turkey test for contact time and number of plants

	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	4 h	7 h	-21.4900	9.21590	0.145	-48.8511	5.8711
		10 h	-26.7100	9.21590	0.056	-54.0711	0.6511
		14 h	-23.5175	9.21590	0.101	-50.8786	3.8436
	7 h	4 h	21.4900	9.21590	0.145	-5.8711	48.8511
		10 h	-5.2200	9.21590	0.940	-32.5811	22.1411
		14 h	-2.0275	9.21590	0.996	-29.3886	25.3336
	10 h	4 h	26.7100	9.21590	0.056	-0.6511	54.0711
		7 h	5.2200	9.21590	0.940	-22.1411	32.5811
		14 h	3.1925	9.21590	0.985	-24.1686	30.5536
	14 h	4 h	23.5175	9.21590	0.101	-3.8436	50.8786
		7 h	2.0275	9.21590	0.996	-25.3336	29.3886
		10 h	-3.1925	9.21590	0.985	-30.5536	24.1686

Based on observed means.
The error term is Mean Square (Error) = 169.866.

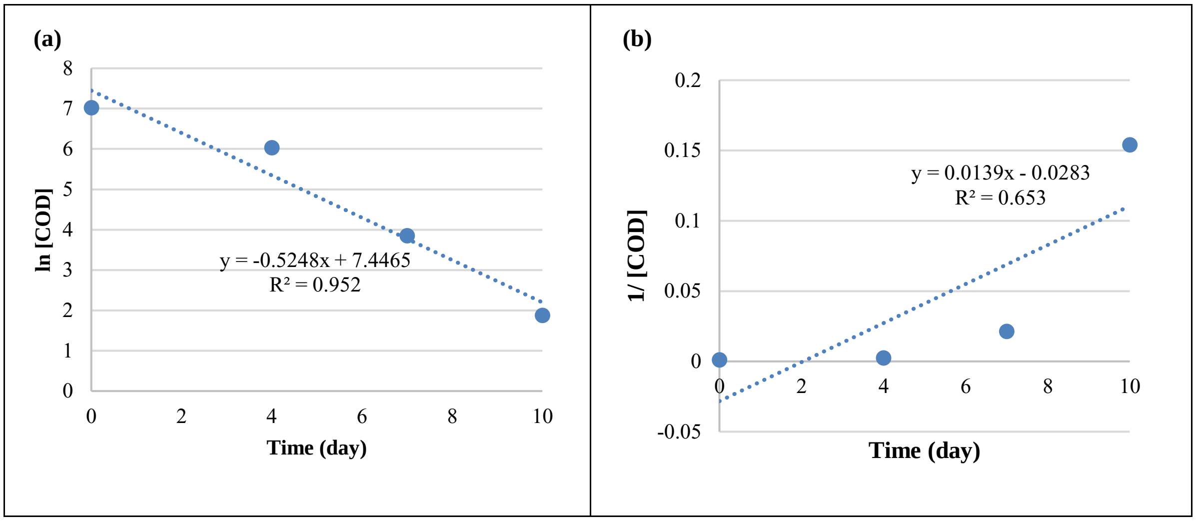

Figure 5. Kinetic data of COD reduction, a) first-order reaction, b) second-order reaction

Conclusion

Phytoremediation reactions were carried out by the plant, and the contact time, initial COD concentration, initial pH of the water sample, and the plant number used in treatment were taken as factors. It was found that *E. aureum* can reduce COD. After analysis, it was found that the highest percentage of removal was 99.42% with a contact time of 10 days, initial wastewater with pH of 6, 75% (v/v) initial COD concentration of wastewater and treatment with 2 plants. Based on the data, *E. aureum* proved to be a good agent for COD removal.

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