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The effect of power plant wastewater concentration on microalgae performance to remove sulfate pollutant: A batch study

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ABSTRACT

Sulfate is defined as a chemical pollutant in industrial wastewater. The presence of sulfate ions in wastewaters leads to problems such as corrosion. The biological method is proposed as an efficient method for sulfate removal. In this study, microalgae were used to remove sulfate pollutant from industrial wastewaters. The purpose of this study is to evaluate the microalgae performance in sulfate removal under various concentrations of power plant wastewater. In this study, the batch liquid culture was used. The wastewater of Fars combined cycle power plant was prepared in four volumetric concentrations (25%, 50%, 75%, and 100%) and used as a microalgae culture medium. *Oocystis sp.* was inoculated in the 10-volumetric percentage of the culture system. The amount of sulfate removal was investigated at certain times over a period of 21 days in different mediums. The results showed that microalgae can remove sulfate at various concentrations of wastewater. The percentage of sulfate removal was increased over time. On the last day, the percentage of sulfate removal in concentrations of 100%, 75%, 50%, and 25% was 32%, 34.71%, 36.16% and, 36.44%, respectively. Due to nutrient reduction, existing in the wastewater, decreasing concentration had not a significant effect on improving the microalgae performance to remove sulfate. Therefore, the application of the biological method with microalgae is a promising option to remove sulfate pollutant from power plant wastewater.

Keywords: *wastewater; power plant; microalgae; sulfate; pollutant; biological method***.**

1. INTRODUCTION

The growth of population, development of urban centers, expansion of industrial activities, and improvement of health levels increase water intake and production of wastewater. These factors produce 3 billion tons of wastewater per year [1-2]. Industries, with using over one billion cubic meters of water per year, play a substantial role in contaminating water resources and have the most impact on reducing water consumption [3-4]. Industrial wastewater is one of the major pollutants of industrial activities such as power plants. There are different pollutants in industrial wastewater. Sulfate is one of the most important chemical pollutants in industrial wastewater, such as power plants [5].

The presence of sulfate ions in industrial effluents causes problems such as corrosion in the wastewater treatment systems and interfering effects in the anaerobic treatment processes. Therefore, sulfate removal from wastewater is necessary [6]. Until now, membrane, chemical, and biological methods have been used to remove sulfate ions from the wastewater [7].

Advantages such as environmental compatibility and the reduction of sludge production have led to the use of biological methods to be more effective for sulfate removal [7]. The use of microalgae is one of the most desirable biological methods to remove pollutants [8]. Microalgae are green phototrophic plants that use sunlight to reduce carbon dioxide, oxidize water, synthesize carbohydrate, and release oxygen [9-10]. Microalgae are introduced as an efficient and suitable option for bioremediation due to their simple structure, high growth rate, wastewater utilization, and the ability to remove various pollutants [11-12].

There are many benefits to use algae in the wastewater treatment systems such as decreasing sludge formation, producing biomass, omitting carbon dioxide, diminishing greenhouse gas emissions, and declining energy consumption. Therefore, many studies have been carried out on the using microalgae to remove various pollutants such as nitrate, ammonium, phosphate, heavy metals, radioactive substances, etc., from wastewater [13-16].

Due to the mentioned advantages to using microalgae in wastewater treatment systems and their ability to remove various pollutants, the purpose of this study is, therefore, evaluating the sulfate removal from the wastewater of Fars combined cycle power plant by using microalgae. To do so, the effect of four-volumetric concentrations (25%, 50%, 75%, and 100%) was studied on the microalgae performance to remove sulfate ions.

2. MATERIALS AND METHODS

2.1 Microalgae.

In this study, *Oocystis sp.* was used. The species was prepared from the Pharmaceutical Science Research Center (PSRC) at Shiraz University of Medical Sciences. Fig. 1 shows the microscopic image of *Oocystis sp.* microalgae with a magnification of 600.

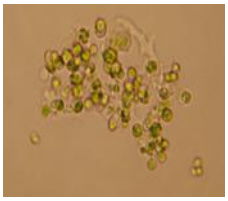

Figure 1. Microscopic image of *Oocystis sp.* microalgae with a magnification of 600.

2.2 Inoculation preparation.

Inoculation bank was prepared in BG11 medium [17]. To do so, liquid culture was used in the batch form and 10-volumetric percentage of *Oocystis sp.* was inoculated into a 50 ml flask containing BG11 medium and kept in the culture conditions for 30 days.

In the cultivating room, the light intensity of 4150 Lux, the temperature of 25 °C, and a 16:8 light-dark cycle were considered as the culture conditions.

2.3 Wastewater.

In this study, the wastewater of Fars combined cycle power plant was used (Fig. 2). The wastewater sample was collected from the wastewater entrance to a small evaporation lake. Table 1 shows the characteristics of the wastewater.

Figure 2. Sampling region at Fars combined cycle power plant.

To reduce the decomposition of compounds before analysis, the sample was stored in the refrigerator at 4 °C. The wastewater was filtered using Whatman 42 filter paper to remove large particles and reduce turbidity and then sterilized by autoclave for 15 minutes at 121 °C and 15 psi.

2.4 Experimental setup.

To evaluate the effect of the concentration of power plant wastewater on microalgae performance in omitting sulfate ions, a batch liquid culture was used. Four concentrations 25%, 50%, 75%, and 100% of the power plant wastewater were prepared by using distilled water so that, the concentration of 100% only contained the wastewater. Different concentrations of wastewater were used as a microalgae culture medium. 40 ml of the various culture mediums was added to a 50 ml flask. After that, the inoculum of microalgae with the concentration of 10-volumetric percentage was added to the different concentrations of the wastewater. Flasks were then placed under culture conditions for 21 days.

Carbon dioxide was supplied from the air and the pH of the samples was not controlled and changed freely. Flasks were stirred manually twice a day. At a given time, culturing systems were sampled to evaluate the amount of sulfate removal.

Table 1. Physical and chemical characteristics of power plant wastewater.

Parameter	Unit	Value
pH	-	8.42
Electrical conductivity (EC)	µS/cm	8925.00
Total dissolved solids (TDS)	mg/L	7130.67
Carbonate (CO_3^{2-})	mg/L	24.00
Bicarbonate (HCO_3^-)	mg/L	97.60
Chloride (Cl^-)	mg/L	106.50
Sulfate (SO_4^{2-})	mg/L	5231.11
Calcium (Ca^{2+})	mg/L	550.00
Magnesium (Mg^{2+})	mg/L	180.00
Sodium (Na^+)	mg/L	1857.97
Potassium (K^+)	mg/L	6.63
Total hardness (T.H)	mg/L	2125.00
Total alkalinity (T.A)	mg/L	100.00
Nitrate (NO_3^-)	mg/L	42.70
Nitrite (NO_2^-)	mg/L	0.01
Phosphate (PO_4^{3-})	mg/L	0.25
Ammonia (NH_3)	mg/L	0.04
Chemical oxygen demand (COD)	mg/L	165.50
Total suspended solids (T.S.S)	mg/L	1.00

2.5 Analytical method of concentration of sulfate.

One ml of the sample (wastewater with microalgae) was removed from the microalgae culture system every five days. Then, the sample was centrifuged to remove microalgae for 5 minutes at 13,000 rpm. After that, the supernatant was used to measure sulfate concentration based on water and wastewater analysis [18]. The concentration of sulfate was determined according to the turbidity measurement methods by using a microplate reader (Bio Tek Microplate Reader XS2, USA) at 420nm. The percentage of sulfate removal was determined according to the equation 1:

The percentage of sulfate removal= $[(C_1-C_2)/C_1] \times 100$ (1)

where C_1 is the initial concentration of sulfate and C_2 is the concentration of sulfate at a defined time. Measuring sulfate concentration was repeated three times at a given time.

3. RESULTS AND DISCUSSION

In this study, the concentration of sulfate in different culture media was determined based on water and wastewater analysis every five days. Table 2 shows the changes of sulfate concentration at different times of microalgae culture and at different concentrations of the culture medium. From Table 2, microalgae decreased the concentration of sulfate ions in various media over time. On the 21st day, as an example, the concentration of sulfate ions in different concentrations of 25%, 50%, 75%, and 100% was 784.54, 1603.8, 2553.67, and 3556.97 mg/L, respectively.

Table 2. Sulfate concentration in different periods of time.

Concentration of medium (%)	Concentration of sulfate (mg/L)					
	Days 1	Days 5	Days 9	Days 13	Days 17	Days 21
25%	1235.73 ± 37.7	1164.49 ± 0.00	980.45± 20.56	900.37± 0.00	820.28± 8.40	784.54± 37.07
50%	2512.11 ± 10.28	1835.33 ± 20.56	1775.97 ± 27.21	1710.73 ± 0.00	1645.48 ± 16.79	1603.80 ± 20.57
75%	3913.17 ± 71.24	2927.68 ± 35.62	2915.84 ± 0.00	2904.00 ± 30.84	2648.78 ± 14.54	2553.67 ± 30.85
100%	5231.11 ± 61.70	3830.05 ± 10.28	3824.18 ± 0.00	3821.23 ± 0.00	3818.30 ± 16.79	3556.97 ± 67.43

The change of sulfate concentration of wastewater by algal cultivation during incubation time is shown in Figures 3 and 4. As it is clear from Figures, at the diverse concentrations of the culture medium, the percentage of sulfate removal was increased with the use of microalgae over time. Therefore, the microalgae performance was positive for sulfate removal at differing concentrations and microalgae can omit sulfate ions from the power plant wastewater at various concentrations of wastewater. In photosynthetic microorganisms, generally, sulfate is absorbed as a source of sulfur by cells and in the plastids reduce to form oligopeptides, vitamins, cofactors, secondary metabolites, and amino acids. Sulfate is defined as the ninth essential macronutrient in photosynthetic microorganisms [19-21].

Fig. 3 reveals that the percentage of sulfate removal decreased with increasing the concentration of power plant wastewater and increasing the concentration of wastewater, in turn, has a negative effect on microalgae performance to reduce sulfate ions. On the other hand, Fig. 4 shows that there is no significant difference in the percentage of sulfate removal in different concentrations of wastewater at different times of microalgae culture and variant media. This is due to the fact that the concentration reduction of power plant wastewater both reduces the concentration of sulfate ions and essential nutrients of culture media. In doing so, the percentage of sulfate removal cannot be increased proportionally to the reduction of power plant wastewater concentration because the essential nutrients for microalgae growth are decreased. Therefore, the results confirmed that although algae can grow and remove sulfate ions at various concentrations of power plant wastewater, dilution of the wastewater, due to the reduction of essential nutrients for microalgae growth and the use of distilled water, is not the suitable approach to improve the amount of sulfate removal.

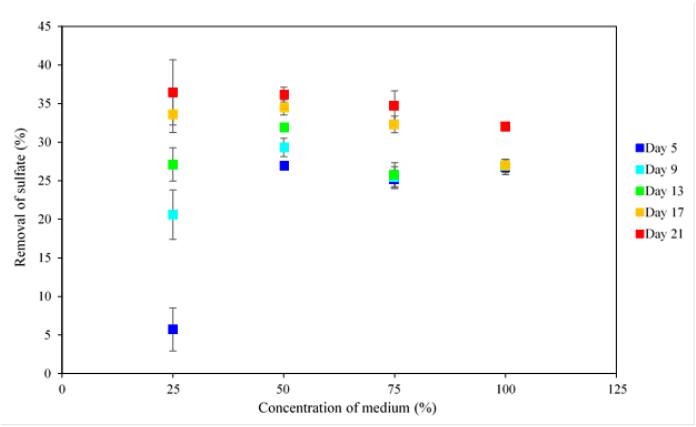

Figure 3. The change in the removal of sulfate as a concentration of medium in different days.

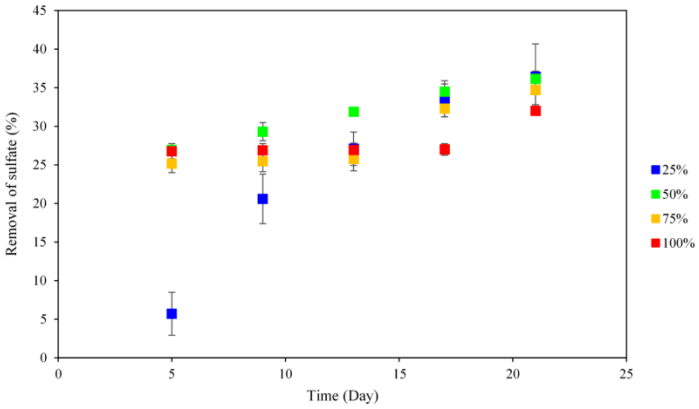

Figure 4. The change in removal of sulfate as time in different concentration of medium.

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4. CONCLUSIONS

The sulfate ion is introduced as a significant pollutant in industrial wastewater, such as power plants. The biological purification method with using microalgae is an appropriate approach that, together with the growth of microalgae, removes sulfate pollutants from wastewater. In this study, results showed that microalgae can grow and remove sulfate in different concentrations of wastewater. Due to the reduction of essential nutrients existing in the wastewater, diluting the wastewater is not suitable to improve the microalgae performance and remove sulfate.

5. REFERENCES

[1] Bhatnagar A., Bhatnagar M., Chinnasamy S., Das K.C., Chlorella minutissima - A promising fuel alga for cultivation in municipal wastewaters, *Applied Biochemistry and Biotechnology*, 161, (1-8),523-536, **2010.**

[2] Jones C.S., Mayfield S.P., Algae biofuels: versatility for the future of bioenergy, *Current Opinion in Biotechnology*, 23, 3, 346-351, **2012**.

[3] Ahmadi M., Tajrishi M., Abrishamchi A., Technical and economic comparison of conventional wastewater treatment systems in the sugar industries in Iran, *Journal of Water and Wastewater*, 53, 54-61, **2005.**

[4] Alavi S.Z., Mojtahedzadeh H., Amin F., Savoji A.P., Relationship between emotional intelligence and organizational commitment in iran's ramin thermal power plant, *Procedia - Social and Behavioral Sciences*, 84, 815-819, **2013.**

[5] Davies T.D., Sulphate toxicity to the aquatic moss, Fontinalis antipyretica, *Chemosphere*, 66, 3, 444–451. **2007.**

[6] Bowell R., A review of sulfate removal options for mine waters, *Proceedings International Mine Water Association Symposium*, 2, 75-88. **2004.**

[7] Lorax Environmental, Treatment of sulphate in mine effluents, *International network for acid prevention*, Australia, **2003.**

[8] Shaker S., Nemati A., Montazeri-Najafabady N., Mobasher M.A., Morowvat M. H., Ghasemi Y., Treating urban wastewater: Nutrient removal by using immobilized green algae in batch cultures, *International journal of phytoremediation*, 17, 12, 1177-1182, **2015.**

[9] Williams Peter J., le B., Lieve ML Laurens., Microalgae as biodiesel & biomass feedstocks: review & analysis of the biochemistry, energetics & economics, *Energy & Environmental Science*, 3, 5, 554-590, **2010.**

[10] Fernández-Linares L.C., Guerrero Barajas C., Durán Páramo E., Badillo Corona J.A., Assessment of Chlorella vulgaris and indigenous microalgae biomass with treated wastewater as growth culture medium, *Bioresource Technology*, 244, 400-406, **2017.**

[11] Halim R., Gladman B., Danquah M.K., Webley P.A., Oil extraction from microalgae for biodiesel production, *Bioresource technology*, 102, 1, 178-185, **2011**.

[12] Villar-Navarro E., Baena-Nogueras R.M., Paniw M., Perales J.A., Lara-Martín P.A., Removal of pharmaceuticals in urban wastewater: High rate algae pond (HRAP) based technologies as an alternative to activated sludge based processes, *Water Research*, **2018.**

[13] http://www.oilgae.com/algae/ap/ap.html.

[14] Kwon H.K., Jeon J.Y., Oh S.J., Potential for heavy metal (copper and zinc) removal from contaminated marine sediments using microalgae and light emitting diodes, *Ocean Science Journal*, 52, 1, 57-66, **2017**.

[15] Mohd Udaiyappan A.F., Abu Hasan H., Takriff M.S., Sheikh Abdullah S.R., A review of the potentials, challenges and current status of microalgae biomass applications in industrial wastewater treatment, *Journal of Water Process Engineering*, 20, 8-21, **2017.**

[16] Bwapwa J. K., Jaiyeola A. T., Chetty R., Bioremediation of acid mine drainage using algae strains: A review, *South African Journal of Chemical Engineering*, 24, 62–70, **2017.**

[17] Stanier R.Y., Kunisawa R., Mandel M., Cohen-Bazire G., Purification and properties of unicellular blue-green algae (order Chroococcales), *Bacteriological reviews*, 35, 2, 171, **1971**.

[18] Kaul A.G., Kaul S.N., *Water and wastewater analysis*, Daya Books, **2002**.

[19] Saito K., Sulfur assimilatory metabolism. The long and smelling road, *Plant Physiology*, 136, 1, 2443-2450, **2004.**

[20] Schiff J.A., Pathways of assimilatory sulphate reduction in plants and microorganisms." *Ciba Foundation Symposium 72-Sulphur in Biology*. John Wiley & Sons, Ltd., 49-64, **1980.**

[21] Lv J., Guo J., Feng J., Liu Q., Xie S., Effect of sulfate ions on growth and pollutants removal of self-flocculating microalga Chlorococcum sp. GD in synthetic municipal wastewater, *Bioresource Technology*, 234, 289-296, **2017.**