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Biodegradation of Linear Alkyl Benzene Sulfonate by Sequencing Batch Reactor in Sanitary Wastewater

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ABSTRACT

Introduction: Detergents lead to many environmental problems. The main aim of this study was to evaluate sequencing batch reactor (SBR) efficiency on Linear alkyl benzene sulfonate (LAS) removal.
Materials and Methods: In this experimental study, to investigate the removal efficiency of LAS, a SBR reactor was used. A roughly 12-hour operating cycle was chosen which included the discharge time (30 min), the filling time (60 min), and sedimentation (1 hr), while the remaining time was devoted to aerating. In this research 48 samples were taken and analyzed. Sampling and testing were performed according to the standard methods of water and wastewater examination.
Results: The results showed that minimum and maximum removal efficiencies of LAS in SBR reactor were 92 % and 99.5 %, respectively. The average removal of COD was 92 %. It was observed that 1 mg/l used surfactants produced 2.3 ± 0.3 mg COD.
Conclusion: It can be concluded that SBR reactor is capable of removing LAS to meet desirable environmental standards.

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Introduction

Municipal wastewater is the main source of pollution in many developing countries. Domestic and industrial consumptions of detergents cause their increase in municipal and industrial wastewater [1, 2].

Generally, detergents are a group of chemicals which have cleaning properties and has a hydrophilic polar and also a branch of non- polar hydrophobic hydrocarbon [3, 4]. The detergent components include: 10-30 % surfactants, 70 % components, sodium silicates, amines, and sodium sulfonate.

Surfactants are large molecules which form the main components of detergents, they are slightly soluble in water and can cause foaming in wastewater treatment plants and receiving water resources [5, 6]. The greatest concern about surfactants is reduction of surface tension and subsequently, oxygen transfer to water [7, 8]. Detergents on the water surface act as a surface layer in aqueous solutions; therefore, they decrease the gas exchange and deplete dissolved oxygen in water which en danger the aquatic animal health. These compounds cause change in taste and smell of water, foam on the surface, disruption in water treatment processes, raise in the costs of treatment, and aquaculture death. They produce fixed foam on the surface of water in concentrations greater than 1 mg/l. The growth of aquatic plants and algae in water increases dissolved oxygen consumption and mortality of aquatic animals [9, 10].

Furthermore, LAS as the largest group of anionic surfactant is decomposed approximately to 90-97 % by bacteria, it exists 3-21 mg/L in sewage and also is decomposed in anaerobic conditions[11,12]. Anionic detergents due to ionization in aqueous solution, separate into two ions; a negative ion, which is a long carbon alkyl chain, and a positive ion which is often sodium. Owing to ionization, cationic detergents transform into positive hydrophobic ammoniumions and negative hydrophilicions, they are also a powerful bactericide[13]. Environmental Protection Agency (EPA) recommended that maximum secondary concentration of foaming agents is 0.5 mg/L while World Health Organization (WHO) expressed that no foaming agent should exist in water. The maximum amount of surfactant is 0.2 mg/L in drinking water, while the standard amount of cationic surfactants is higher[6]. Institution of Standard and Industrial Research of Iran has determined 200 mg/L detergents in drinking water as maximum [14].

However, there are different ways to treat wastewaters containing LAS. Sequencing Batch Reactor (SBR) is one of them that has been widely applied for treatment of LAS and consists of filling, aeration, settling, decantation, and idling phases in the same reactor. Usually, the operational condition can be classified into anaerobic, anoxic, or oxic (aerobic) processes [15]. In the studies carried out by Schleheck and Huang and Eichhorn and knepper, it was showed that removal efficiency of LAS in activated sludge system was more than 95 % with 70-80 % biodegradability [16]. In a study conducted by Michaell et al., LAS removal efficiency in activated sludge, trickling filter, and rotating biological systems was reported as 99.5 %, 82.9 %, and 99 %, respectively [17]. Sedlak et al. studied the effect of SRT on detergent removal and concluded that LAS removal efficiency depends on SRT. Moreover, there was 0.02 mg/l LAS in the effluent while SRT and LAS influents were 3.2 days and 5 mg/l, respectively. When SRT changed to 0.8 day, LAS effluent concentration was 0.05 mg/l [18]. The main aim of this study was to evaluate SBR efficiency on LAS removal.

Materials and Methods

In this experimental study, to investigate the LAS removal efficiency, a SBR reactor was applied which was made of plexiglass. Table 1 shows the general specifications of the reactor. Figure 1 also shows the pilot of SBR.

Table 1: Specifications of SBR pilot

Characteristics	Amount
Length (m)	0.14
Width (m)	0.14
Diameter (m)	0.2
Total height (m)	0.3
Free board (m)	0.05
Useful height (m)	0.25
Filling height (m)	0.15
Volume (l)	6
Filling volume (l)	3
Total hydraulic retention time (hr)	12
MLSS (mg/l)	4200
MLVSS (mg/l)	3000

Figure 1: The SBR pilot with injection pump

The system consists of a SBR reactor, synthetic wastewater tank, feed pump, discharging tap, aeration equipment, two wastewater collection tanks, and an Electrical processor (Japan, Omron Co, CPM2A - 60CDR – model). An operating cycle of about 12 hr was chosen which included discharge (30min), filling (60min), sedimentation (1hr), and aerating (the remaining time) processes.

Additionally, in order to provide the required trace elements, synthetic substrate containing glucose as its main component, ammonium acetate as a source of nitrogen, potassium dihydrogen phosphate and nitrogen source, sodium bicarbonate, sulfate, nickel sulfate, chloride, calcium, iron, and cobalt, magnesium sulfate, and sodium were used. Then, reactor was launched with 250 mg/l COD loading rate. Further, the influent COD loading rate was changed to 300 mg/l and then to 500 mg/L. During 3 weeks the COD removal efficiency in the reactor was fixed. After that LAS was added to the influent in concentrations of 5, 10, and 20 mg/L during 9 weeks. By taking a sample from the influent and effluent of the reactor, LAS removal efficiency was determined. The system was operated by dissolved oxygen in the range of 2-3 mg/L and 12 hr as HRT. In this research, COD and LAS were measured in DR 2000 in wave length of 605 nm(Hach Co, United States), while suspended solids measured by gravimetric method and SVI also was measured by volumetric method (Imhoff cone). The other parameters such as DO, pH and temperature were measured by a Yallow Springs Instroment (YSI) portable device.

Statistical analysis

For analyzing data and comparing the achieved results with the standard values, T-Test was performed through the SPSS software (ver18).

Results

To investigate the removal efficiency of the LAS, parameters of COD, LAS, pH, dissolved oxygen, temperature, MLSS, SVI, and amount of air consumption were measured frequently. Table 2 to 4 shows the calculated data such as mean, standard deviation, minimum and maximum values.

Table 2: The measured parameters in concentration of 5 mg/l surfactants in the influent substrate in designed SBR pilot

Parameter	Mean	SD	Min	Max
Surfactant concentration in input substrate (mg/l)	4.99	0.02	4.98	8
Surfactant concentration in output substrate (mg/l)	0.19	0.12	0.02	0.36
Surfactant removal efficiency (%)	96	-	92	99.5
COD in input substrate (mg/l)	512	1.32	508	513
COD in output substrate (mg/l)	40.63	22.25	12.9	62.5
COD removal efficiency (%)	92	-	89	97
pH	-	0.31	7.7	8.5
Temperature (° C)	21.18	0.31	20.7	21.7
Dissolved oxygen (mg/l)	2.39	0.47	1.48	3
Air consumption (l/min)	7	1.45	5.6	8.5

Table 3: The measured parameters in concentration of 10 mg/l surfactants in the influent substrate in designed SBR pilot

Parameter	Mean	SD	Min	Max
Surfactant concentration in input substrate (mg/l)	11.99	0.02	11.98	12.01
Surfactant concentration in output substrate (mg/l)	0.4	0.34	0.18	0.97
Surfactant removal efficiency (percent)	97	-	92	99
COD in input substrate (mg/l)	529.22	0.74	528.6	530
COD in output substrate (mg/l)	47.41	17.63	30	70.7
COD t removal efficiency (percent)	91	-	87	95
pH	-	0.16	7.8	8
Temperature (° C)	20.66	0.4	20.3	21.5
Dissolved oxygen (mg/l)	2.47	0.29	2	3
Air consumption (l/min)	11.5	1.32	10.5	13

Table 4: The measured parameters in concentration of 20 mg/l surfactants in the influent substrate in designed SBR pilot

Parameter	Mean	SD	Min	Max
Surfactant concentration in input substrate (mg/l)	20	0.02	19.98	20.01
Surfactant concentration in output substrate (mg/l)	0.59	0.55	0.24	1/7
Surfactant removal efficiency (percent)	97	-	92	99
COD in input substrate (mg/l)	551.03	2.21	548.7	552.9
COD in output substrate (mg/l)	43.96	16.61	30.96	74.3
COD t removal efficiency (percent)	92	-	86	94
pH	-	0.2	7	7.5
Temperature (° C)	20.8	0.31	20.2	21.2
Dissolved oxygen (mg/l)	2.44	0.28	1.93	2.6
Air consumption (l/min)	19.7	0.1	19.6	19.8

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Figures 2 and 3 show the concentration and removal efficiency of COD in effluent when surfactant concentrations were 5, 10, and 20 mg/l. Figures 4 and 5 also represent the LAS concentration and its removal efficiency in effluent.

The results of this study showed that COD removal efficiencies were 97 %, 95 %, and 94 % when influent LAS loading rates were 5, 10, and 20 mg/L, respectively. System also was stable in the eighth weeks. The average COD concentration and its removal percentage in effluent were 96.43 mg/L and 92 %, respectively.

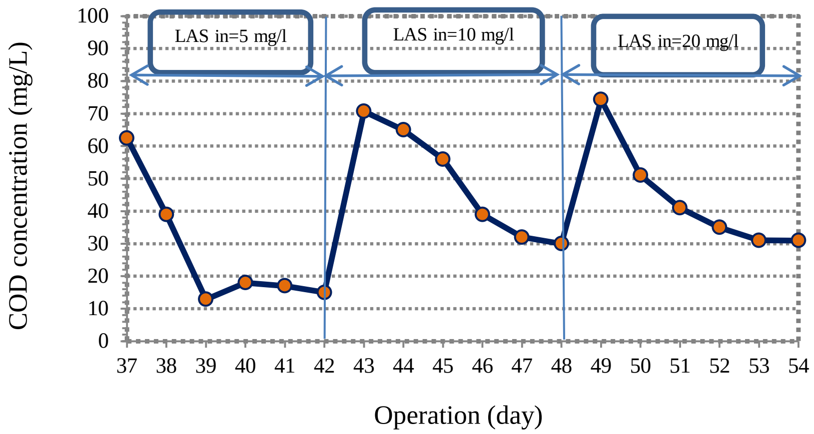

Figure 2: COD variarions during LAS adding through the operation time

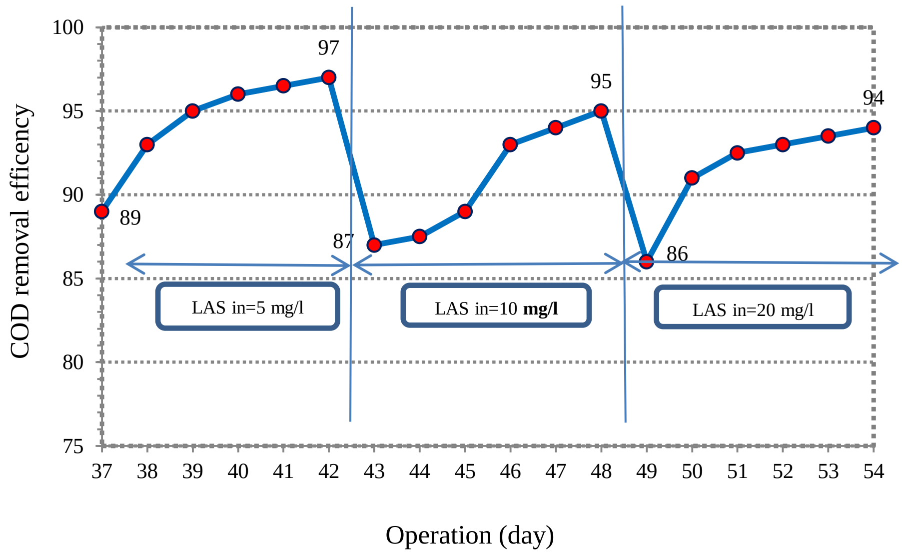

Figure 3: COD removal efficency during LAS adding through the operation time

According to Figure 4 and 5, LAS concentrations in influent were 5, 10, and 20 mg/l while LAS removal efficiencies were 99.5 %, 99 %, and 99 %, respectively. After eight weeks, the average concentration of surfactant in effluent was 6 ± 0.55 mg/l with 97 % removal efficiency. Generally, it is claimed that different LAS concentrations (5, 10, 20 mg/l) did not have any significant effect on the removal efficiency.

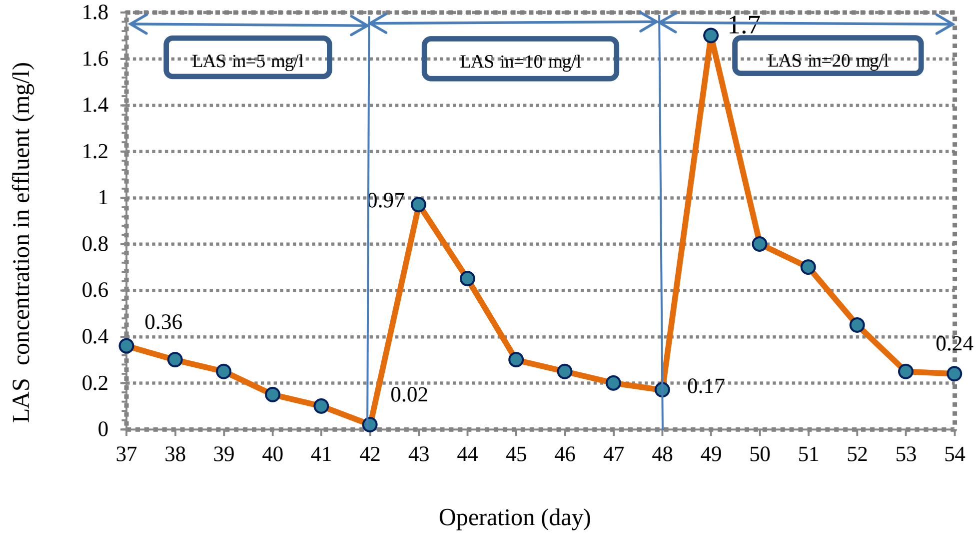

Figure 4: LAS variations during the operation time

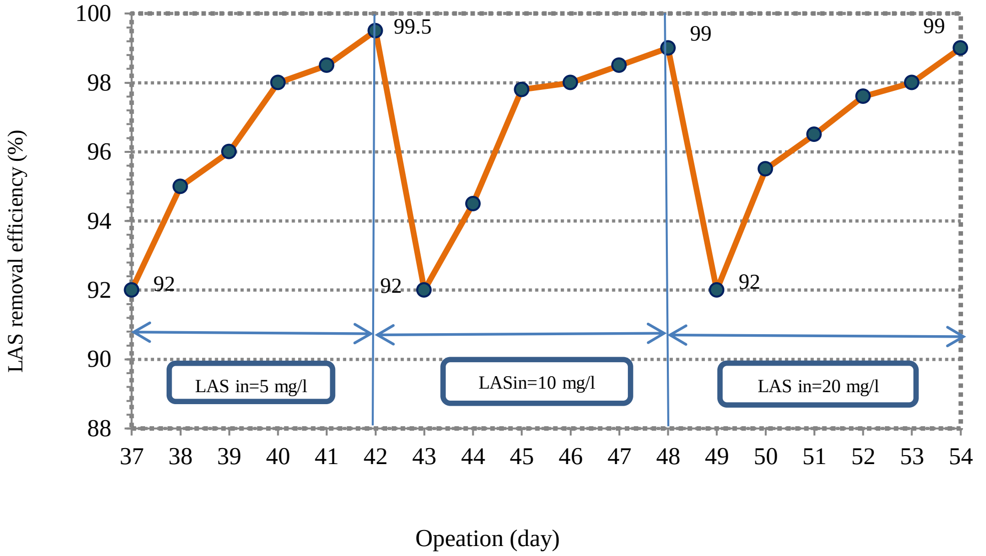

Figure 5: LAS removal efficiency in effluent during the operation time

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Discussion

This study represented that the addition of surfactant to influent substrate do not have any significant effect on COD removal efficiency. Since LAS is classified as an ionic surfactants, it does not have a significant effect on microorganisms which play an important role in biological systems [18]. Researches also showed that wastewater treatment plants neither are affected by LAS concentration nor have much effect on them. Haberl investigated the effect of 30–40 mg/l Methylene Blue Active Substances (MBAS) on wastewater treatment and reported that no significant malfunction was observed while sludge sedimentation decreased [19]. In a study conducted by Okada et al, the results showed that 10 mg/l

LAS did not affect the system, while a sudden change of LAS concentration to 50 mg/l reduced COD removal efficiency. But after two weeks it returned to normal conditions. In the current study, the surfactant concentration had a low effect on removal efficiency of different concentrations of COD. The average surfactant concentration in effluent was 0.24 mg/l, which was lower than the standard discharge to the environment.

Sedlak et al. studied the effect of SRT to remove detergent. Their research showed that there was 0.02 mg/l LAS in effluent while SRT and LAS influents were 3.2 days and 5 mg/l, respectively. When SRT changed to 0.8 day, effluent LAS concentration was 0.05 mg/l[19]. Studies carried out by Schleheck and Huang in 2000 and Eichhorn and knepper in 2002 represented that the removal efficiency of LAS in activated sludge system was more than 95 % with 70-80 % biodegradability [16]. In another study by Michaell et al., LAS removal efficiency in activated sludge, trickling filter, and rotating biological systems were investigated. LAS removal efficiency was reported 99.5 %, 82.9 %, and 99 %, respectively [17]. German researchers compared the removal efficiency of LAS in conventional activated sludge system and floating platforms. They claimed that these 2 systems applied biological processes and had more than 97 % LAS removal efficiency. Anionic surfactant removal by activated sludge system was carried out by D. Parts in 1997 with 99.4 % system efficiency [17]. The results of this study were similar to those of other studies around the world. Therefore, it can be concluded that more than 90 % of LAS can be removed by activated sludge system.

Conclusion

The results showed that per each mg of used surfactant, COD was 2.3 ± 0.3 mg/l. increasing the influent LAS concentration, caused pH reduction inside the aeration reactor. The SBR activated sludge system was also capable of LAS removal to reach the existing environmental standards. LAS increasing in this research has no effect on the efficiency of wastewater organic loading rate by SBR system. The minimum and maximum of LAS removal efficiency in SBR activated sludge reactor during stability were 92% and 99.5%, respectively.

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Conflict of interest

We have no competing interests.

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