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Removal of Sodium Dodecyl Sulfate in an Intermittent Cycle Extended Aeration System

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Abstract: The objective of this study was to investigate the removal of an anionic surfactant from wastewater in ICEAS. The surfactant considered here was anionic SDS being widely used in the household and industrial detergents. Basic wastewater COD was 260 mg L^{-1} and SDS surfactant added in range 20 to 400 mg L^{-1}. The effect of the inlet SDS concentration and reaction time on COD and SDS removal was investigated. The results from this study indicated that the aeration time of 2 h was sufficient for removal of SDS ranged 20 to 400 mg L^{-1}. Obtained data showed low effluent SDS concentrations of 0.3 to 5 mg L^{-1} and removal of SDS was more than 98%. These results revealed that biological treatment using ICEAS process is capable to treating wastewaters containing high concentration of SDS surfactant.

Key words: Sodium dodecyl sulfate, intermittent cycle, extended aeration system

INTRODUCTION

Surfactants are organic compounds that reduce surface tension in water and other liquids (Kowalska *et al*., 2004). In the domestic wastewater produced by the households, surfactants invariably exist in significant amounts due to detergents used for all kinds of washings. Surfactants have also been widely used in textiles, fibers, food, paints, polymers, cosmetics, pharmaceuticals, mining, oil recovery and pulp and paper (Sheng *et al*., 1999). These applications of the surfactant, increasing its discharge in the wastewater, produce foam and enter into the underground water resources and constituting an ecological risk for aquatic organisms (Nasiruddin and Uzva, 2005). They contain both strong hydrophobic and hydrophilic moieties. According to the charge of their hydrophilic moiety, surfactants can be classified into four categories: anionic, non-ionic, cationic and amphoteric (Mozia *et al*., 2005). Anionic surfactants are one of the most frequently employed surfactants and constitute approximately two-third of these surfactants. Cationic surfactants constitute less than 10% of the ionic surfactants and rest is anionic surfactant. Thus Anionic Surfactants (AS) are the major class of surfactants used in detergent formulations. The predominant class of anionic surfactant is linear Alkylbenzene sulfonate and linear alkyl sulfate (Liwarska and Bizukojc, 2006). As a result, their fate in the environment has been widely studied. An example of linear alkyl sulfate is Sodium Dodecyl Sulfate (SDS), which is a representative of AS (Adac *et al*., 2005). The common procedures for surfactant removal from the water and wastewater include processes such as chemical precipitation (Aboulhassan *et al*., 2006), photocatalytic degradation (Mozia *et al*., 2005), oxidation (Sheng *et al*., 1999; Adams and Daigger, 1999), adsorption (Nasiruddin and Uzva, 2005), membrane technology, various biological methods (Langford *et al*., 2004) etc. Recently, Biodegradation of anionic surfactants in wastewater treatment processes has been the subject of the substantial research. The activated sludge process is an aerobic biological stage in wastewater treatment that oxidizes organic matter to carbon dioxide and water, generating new biomass (Langford *et al*., 2004). Intermittent Cycle Extended Aeration System (ICEAS) is type of activated sludge process that influent wastewater is fed continuously through the cycles of react, settling and decant (Metcalf and Eddy, 2003). The single reactor in this system has the functions of bio-oxidation, nitrification, denitrification, phosphorus removal, settlement and sludge stabilization (Jing *et al*., 1999). The aim of the present study was to investigate the performance of ICEAS process in removal SDS of wastewater.

MATERIALS AND METHODS

Inoculum and wastewater composition: Synthetic sewage was used to simulate wastewater and fed continuously at a constant flow rate of 0.5 L h^{-1}. To simulate wastewater, a base feed of glucose was used. Ammonia and

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Table 1: Synthetic wastewater characteristics

Substrate	Concentration (mg L^{-1})
COD	260
BOD_5	208
Ammonia nitrogen	25
Phosphate	5

phosphate sources were di-ammonium hydrogen phosphate $(NH_4)_2HPO_4$ and Ammonium chloride (NH_4Cl). The COD:N:P ratio was 100:5:1. The activated sludge taken from the aerated chamber at wastewater treatment plant in Ecbatan, Tehran was used as an inoculum. Surfactant studied was sodium dodecyl sulfate in range 20 to 400 mg L^{-1}. Synthetic wastewater composition (Table 1).

Experimental set up and procedure: This study was carried out at the Tarbiat Modares University, Tehran, Iran. The investigated reactor in this study is shown in Fig. 1. The reactor was a 20×20×30 cm (H×W×L) polexyglass tank which was equipped with diffuser air. Wastewater was feed using a dosing pump continuously through openings at the bottom of the baffle wall and into the main react zone. After aeration and settling, separated liquid is removed by an automated, time-controlled decant mechanism. Solids Retention Time (SRT) was 30 days. It was operated with a dissolved oxygen content of 3-5 mg L^{-1} during aeration cycle and 0.25 mg L^{-1} during settling cycle. Each experiment was conducted for between 5-7 days until a steady state condition was achieved. The effluent was analyzed every 12-24 h. Duration of first run was 3 h include 2 h reaction, 45 min settling and 15 min decanting. In run 2, reaction time was 3 h.

Analysis techniques: A rapid and reliable solvent extraction spectrophotometric method has been developed for the determination of SDS. Acridine orange (ACO) (λ_{max} = 467 nm) has the potential for being used as an ion-pairing agent with SDS. The ion-pair formed between SDS and ACO is extractable in toluene. Sample solution (10 mL) containing SDS was poured into a 25 mL separating funnel. ACO (5×10^{-3} M) and glacial acetic acid 100 μL each was added. Then 5 mL of toluene was added to it and shaken for 1 min. The aqueous layer was then discarded and the toluene layer was used for absorbance measurement at 467 nm (Adac *et al.*, 2005). Chemical oxygen demand (5220B), total suspended solids (2540B), volatile suspended solids (2540E), Sludge volatile index (2710D) Ammonia (4500C) and phosphate (4500C) were measured according to Standard Methods (1998).

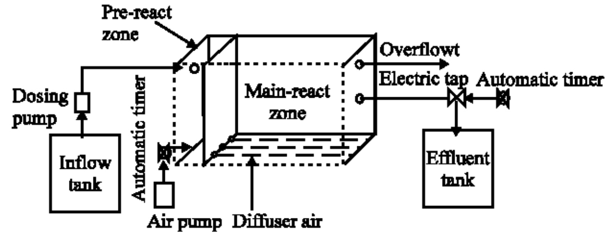

Fig. 1: Flow diagram of the investigated system

RESULTS AND DISCUSSION

For a bench scale reactor treating a synthetic wastewater containing various concentrations of SDS, removal achieves in ICEAS process configuration tested. In run 1 (COD = 260 mg L^{-1}), inlet SDS concentration started of 20, 50, 100, 200 and 400 mg L^{-1}, respectively. Chemical Oxygen Demand (COD) equivalent for SDS was about 1.8 mg mg^{-1} SDS. Base initial COD concentration (260 mg L^{-1}) increased with the increase of the surfactant value to 290, 350, 430, 600 and 900 mg L^{-1}. MLSS in the above mentioned inlet SDS concentrations at the beginning of aeration cycle were about 2800, 3000, 3500, 4500 and 6000 mg L^{-1}, respectively. Results of SDS removal (runs 1 and 2) (Fig. 2, 3). In run 1, effluent SDS for the mentioned SDS concentrations (20, 50, 100, 200 and 400 mg L^{-1}) was 0.3, 0.64, 1.47, 2.5 and 4.57 mg L^{-1}, respectively. In addition, these values in run 2 for the concentrations of 50, 100, 200 and 400 mg L^{-1} were 0.57, 1.29, 1.37 and 2.12 mg L^{-1}, respectively. Table 2 depicts the performance of the ICEAS in terms of COD in the effluent wastewater. Effluent COD and SDS decreased from the first run to the second run. Also with the increase of SDS concentration, effluent COD increased slightly. The Sludge Volume Index (SVI) was determined as an indicator of sludge settling capacity (Fig. 4). SVI values in ICEAS decreased with the increase of SDS concentration.

From the results (Fig. 2, 3) it is observed that removal yield of SDS was more than 98%. These results are close to Luis' observations (2004), who showed that the removal efficiency of SDS in ICEAS is more than 95%. Ebrahimi *et al.* (2006) studied removal of LAS in municipal wastewater (concentration of 20 mg L^{-1}) Conventional Active Sludge (CAS) and Fixed bed Active Sludge (FAS) and removal efficiency of LAS reported 93 and 97%, respectively. In this study, removal efficiency of COD in conventional active sludge system was 87% (Ebrahimi *et al.*, 2006). In addition, in a study of SDS biodegradation by the *Acinetobacter* isolated from active sludge, removal efficiency was 96.4% (Hosseini *et al.*, 2007). These results revealed that the efficiency of our

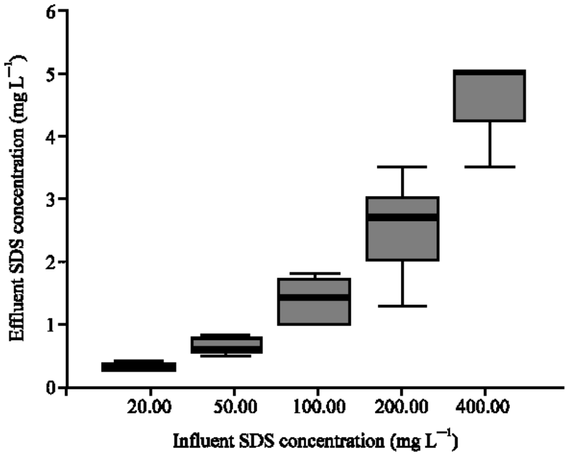

Fig. 2: Removal of SDS as a function of inlet concentration in Run 1

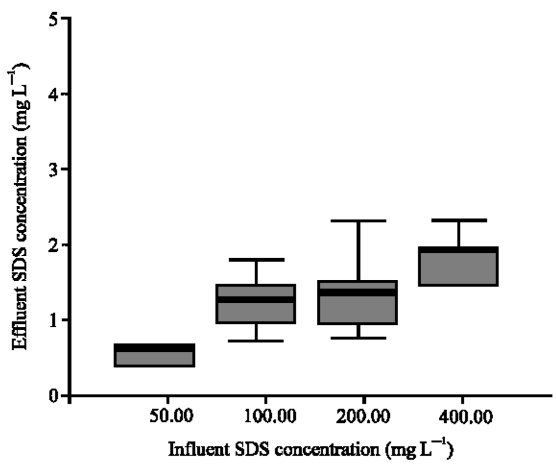

Fig. 3: Removal of SDS as a function of inlet concentration in Run 2

Table 2: Effluent concentration variation of COD as a function of Inlet SDS and COD concentration in runs 1 and 2

SDS (mg L^{-1})	Influent COD±10 (mg L^{-1})	Effluent COD±2.5 (mg L^{-1}) Run 1	Run 2
20	290	<10	-
50	350	10	<10
100	430	15	<10
200	600	25	10
400	900	30	15

ICEAS in COD and SDS removal was higher than the other reported systems. Generally, it is found that ICEAS processes with longer hydraulic retention time and intermittent aeration usually produce better effluent with respect to COD, than conventional processes (Bicudo and Svobada, 1995). IEPA (1999) has set a value of 1.5 mg L^{-1} for anionic surfactants to discharge to the surface waters. With the inlet concentration of SDS 200 mg L^{-1}, effluent SDS concentration in run 1 was more than IEPA standard

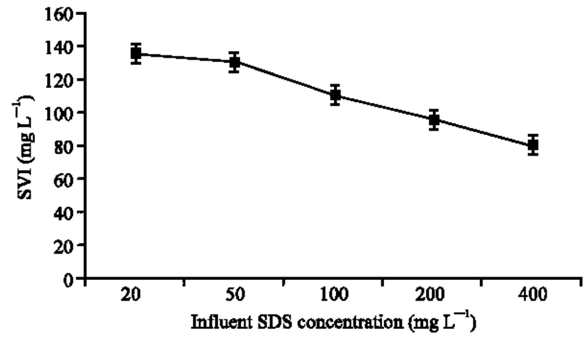

Fig. 4: Variation of Sludge Volume Index (SVI) with the SDS concentration

and for achieving to IEPA standard, the aeration cycle time was increased to 3 h. In these conditions, SDS concentration in the effluent was 1.37 mg L^{-1}. Moreover, in run 2 and SDS concentration of 400 mg L^{-1}, effluent concentration of the tested pollutant was 2.12 mg L^{-1}. If higher removal efficiency is needed, increase of the aeration time or tertiary treatment such as adsorption on activated carbon could be a suitable alternative. From point of view of sludge settling characteristics, SVI during the entire course of the experiment was within the generally accepted range of 50-150 mg L^{-1}. SVI values in the tested ICEAS decreased with the increase of SDS concentration (Fig. 4). It was due to the decrement of activated sludge floc dimensions, which was a result of saponification (Liwarska and Bizukojc, 2006). One of disadvantages observed in the ICEAS was accumulation high concentrations of surfactant during the settling period that caused foam production (>100 mg L^{-1}) as soon the aeration was started. This foam adsorbed after ten minutes by sludge solids. It recommends that eliminate the foaming problem due to high concentrations of SDS using anti-foaming agents. Totally, ICEAS process is capable to reduce carbon materials (include surfactant), phosphate and nitrate in industrial and domestic wastewaters with the repeated cycles of aeration/settling in single activated sludge (Jing *et al*., 1999; Luis, 2004). Therefore, based on the results from this study, we can utilize this system to biological treatment of surfactant wastewaters in full-scale plants and in comparison to other biological systems, chemical processes and advanced oxidation methods; this process is an effective alternative.

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