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Validation of linear and non-linear kinetic modeling of saline wastewater treatment by sequencing batch reactor with adapted and non-adapted consortiums

Mohammad Mehdi Amin [a], Mehdi H. Khiadani (Hajian) [a,c], Ali Fatehizadeh [a,b], Ensiyeh Taheri [a,b,*]

[a] Environment Research Center, Isfahan University of Medical Sciences (IUMS), Isfahan, Iran
[b] Department of Environmental Health Engineering, School of Health, Student Research Center, IUMS, Isfahan, Iran
[c] School of Engineering, Edith Cowan University, WA 6027, Australia

HIGHLIGHTS

- The biokinetic models were tested in SBRs treating saline wastewater.
- The Grau second-order model gave a better description of the substrates removal.
- The prediction ability of Monod and Contois models were decreased at SRT<4 d.
- Salinity can influence on bacteria kinetic coefficients for wastewater treatment.

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ABSTRACT

Microbial characteristics and behavior were undertaken for the treatment of synthetic saline wastewater. Two sequencing batch reactor (SBR) with non-adapted and adapted inoculum (SBR1, SBR2) to saline wastewater and various initial NaCl and chemical oxygen demand (COD) concentrations were operated. In both SBRs, the initial COD of influent wastewater was gradually progressed to 3000 mg/L, whereas NaCl content increased up to 10,000 mg/L. The average of COD reduction in SBR1 and SBR2 was obtained 96 and 95%, respectively. The kinetic modeling showed that the experimental data from saline wastewater treatment by SBRs were fitted well to the Grau second order kinetic model (R^2: 0.99). Model evaluation was then carried out by calculating the linearity between the observed data and predicted values. The result confirmed that in comparison with First and Grau second-order kinetic models, the Monod and Contois models were not suitable in solid retention time (SRT) < 4 d. As SBRs operated at SRT > 4 d, the salinity can cause lower fluctuation in SBR efficiency. Among the non-linear kinetic models, the Grau second-order model gave a better description of the substrate consumption than the typical Monod, Contois and First order model for the saline wastewater treatment in this study.

1. Introduction

Hypersaline wastewater is brines which contains organic compounds with at least 3.5% w/v total dissolved solids. It is produced by various industries such as pesticides, herbicides, polyhydric compounds, organic peroxides, pharmaceuticals, tanneries, seafood processing, petroleum, and textile [1–4].

Problems with biological treatment of high saline wastewater include low BOD (biochemical oxygen demand) and COD (chemical oxygen demand) removal, increase of effluent turbidity, decreases of solids and microbial population, change in activated sludge, and degradation of kinetic reduction [5–7].

Previous researches have shown that high saline wastewater leads to plasmolization or reduction of bacterial activity [5,8]. Adverse effect of salinity on treating wastewater was observed in systems such as conventional activated sludge (CAS), extended aeration, rotating biocontactor, nitrification and denitrification [6]. The recommended solutions to this problem include the use of: (i) salt-tolerant halophilic organisms as a singly or in activated sludge culture, (ii) pure halophilic bacteria, (iii) inoculation of halophilic bacteria [6], and (iv) adaption of non-salt-adapted microorganisms to increasing salt concentration. The success of these methods depends on factors such as type and growth phase of microorganisms. It has been reported that adverse impact of rapid change of salt concentration is more than gradual shift [1].

* Corresponding author at: Environment Research Center, Hezar Jerib Ave., Isfahan University of Medical Sciences, Isfahan, Iran.
E-mail address: e_taheri_83@yahoo.com (E. Taheri).

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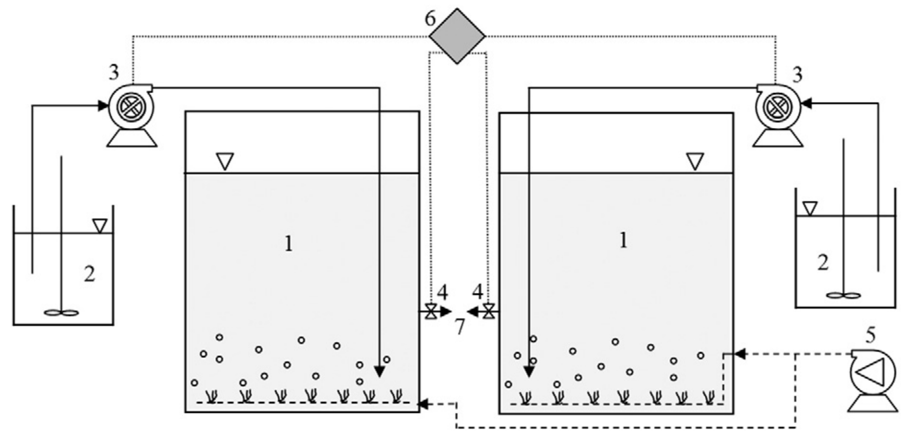

Fig. 1. Schematic diagram of the experimental set-up for the SBRs: (1) bioreactor, (2) feed tank, (3) influent pump, (4) electrical valve, (5) air compressor, (6) PLC and (7) effluent wastewater.

Adaptations to new conditions require changes in the metabolic characteristic of bacteria populations [9]. The question is whether the adaptation causes changes in kinetic properties of bacterial or not?

The main object of this study was investigating the bacterial adaptation to salinity by considering the characteristics of bacterial populations such as COD removal efficiency in order to validation of linear and non-linear kinetics for SBR modeling of saline wastewater treatment with adapted and non-adapted consortiums.

2. Materials and methods

2.1. SBRs

In this study, two identical SBRs were used and constructed of Plexiglas having a working volume of 5 L and dimensions of 16.5 × 16.5 × 35.5 cm (L × W × H). The schematic diagram of the experimental set-up is shown in Fig. 1.

The SBRs were operated in 24 h cycle including 10 min feeding, 22:40 h aeration and reaction, 1 h settling and 10 min decant time. For this purpose, a programmable logic controller (PLC, S7 224CPU, Siemens) was used. The inoculum biomass was collected from two municipal wastewater treatments. The first reactor (SBR1) was inoculated with extracted biomass from south of Isfahan wastewater treatment plant (SIWWTP) which was salt free wastewater and in the case of second reactor (SBR2); the biomass was brought from Hormozgan wastewater treatment plant (HWWTP) which adapted with saline wastewater [10]. At the biomass collection time for SBR2, the influent wastewater EC into the HWWTP was 9061 μS/cm. The properties of seed biomass into SBRs are summarized in Table 1.

2.2. Synthetic substrate

Glucose was used as a sole substrate with concentration of 500–3000 mg/L (COD). Essential elements for microorganism growth were also added to the synthetic substrate [10]. The initial salt contents of influent wastewater into SBR1 and SBR2 were 500 and 2000 mg/L NaCl, respectively. During operation of SBRs over 1 year, the initial salt concentration of influent wastewater gradually increased to 10,000 mg/L by NaCl addition.

2.3. Experiments

The pH and EC of influent and effluent wastewater from SBRs were routinely measured. The solution pH of influent wastewater and dissolved oxygen concentration in the SBRs was adjusted in the range of 7–8 and 2–5 mg/L, respectively. All test methods were adapted from standard methods for water and wastewater experiments [11].

3. Results and discussion

3.1. Reactor efficiencies

Table 2 illustrates the phases of the study and the purpose considered in each phase of the experiment along with the range of investigated variables in both reactors.

The removal of COD during SBR operation was studied with gradual increasing of initial COD and NaCl concentration in parallel. Figs. 2 and 3 have shown the COD removal efficiency of SBR1 and SBR2 in function of initial COD and NaCl concentration of influent synthetic wastewater. As seen in Fig. 2, at initial NaCl concentration equal to 5000 mg/L of influent wastewater, the maximum COD removal efficiency of SBR1 was obtained and corresponded to 98.5%. Results revealed that as the initial salinity concentration increased from 500 to 5000 mg/L, the removal efficiency of COD slightly ascended from 90% to 99%. After this point, the

Table 1
Characteristics of biomass as inoculum into SBRs.

Parameter	SIWWTP biomass	HWWTP biomass
TDS (mg/L)	738	3460
VSS (mg/L)	6520	22,430
EC (μS/cm)	1381	5930

Table 2
Experimental phases and SBRs operation schedule.

SBR operation period (d)		EC (mS/cm)		Solution pH	
SBR1	SBR2	SBR1	SBR2	SBR1	SBR2
1 – 20	1 – 20	2.7	6.2	8	8.1
21 – 31	21 – 30	3.5	6.3	8.2	7.9
32 – 41	31 – 38	4.9	8.0	8.4	8.2
42 – 50	39 – 47	6.1	9.6	8.5	8.4
51 – 60	48 – 55	7.0	10.3	8.4	8.2
61 – 88	56 – 83	9.5	12.8	8.2	8.4
89 – 102	84 – 104	10.5	13.2	8.2	8.3
103 – 110	105 – 120	10.2	14.2	8.5	8.3
111 – 118	121 – 135	12.5	16.3	8.4	8.4
119 – 130	136 – 145	14.7	18.5	8.3	8.2
131 – 138	146 – 165	17.6	19.0	8.3	7.6
139 – 162	166 – 269	19.5	21.2	8.2	7.7
163 – 172	–	21.7	–	7.7	–
173 – 269	–	22.5	–	7.6	–